Introduction To Remote Sensing for Air Quality Application

TCEQ Training Course
February 24 – 27, 2014

ARSET

Applied Remote SEnsing Training

A project of NASA Applied Sciences

Objectives

- Provide exposure to the most useful products and tools for air quality applications
- Promote proper use of data and tools
- Assist users in organizing information

Objectives

Promote proper use of data and tools

Theory and background information

- Core remote sensing products
- Understand strengths and weaknesses
    1. Data
    2. Tools

- Evaluate the quality of tools and data

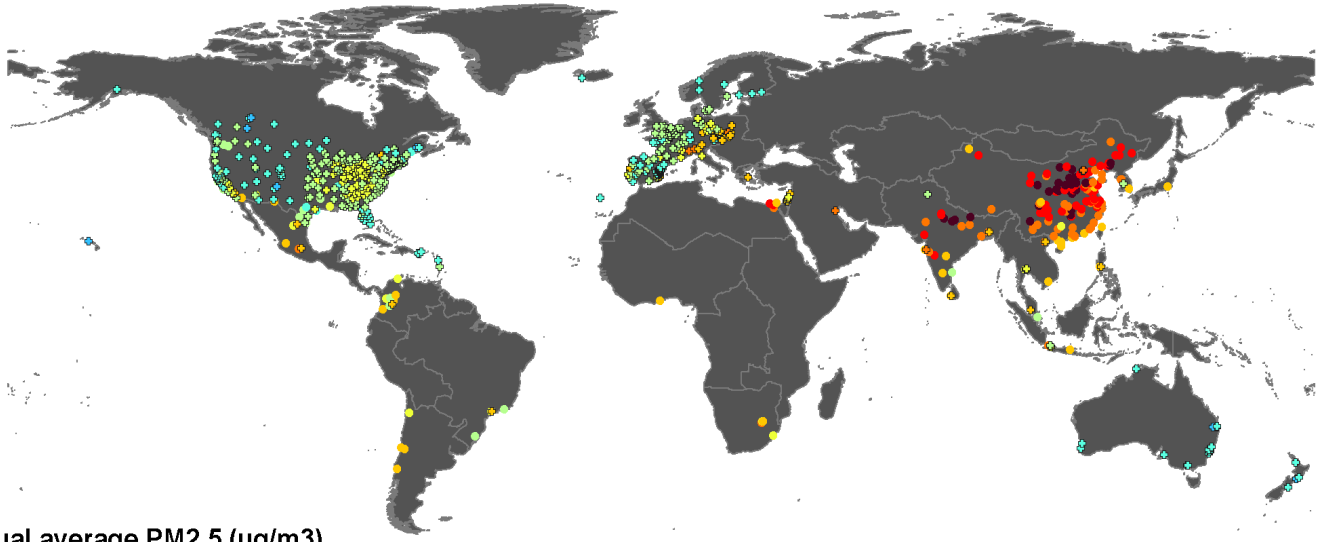
Where are we now and where are we going? Capabilities in Remote Sensing and Air Quality Applications

ARSET - AQ

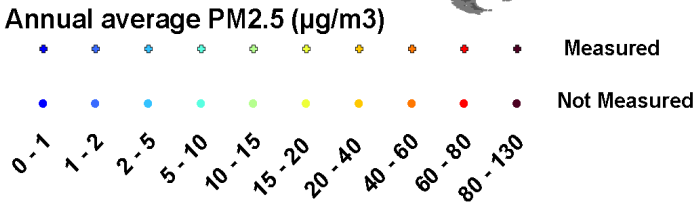
Applied Remote SEnsing Training – Air Quality

A project of NASA Applied Sciences

Global Status of PM2.5 Monitoring

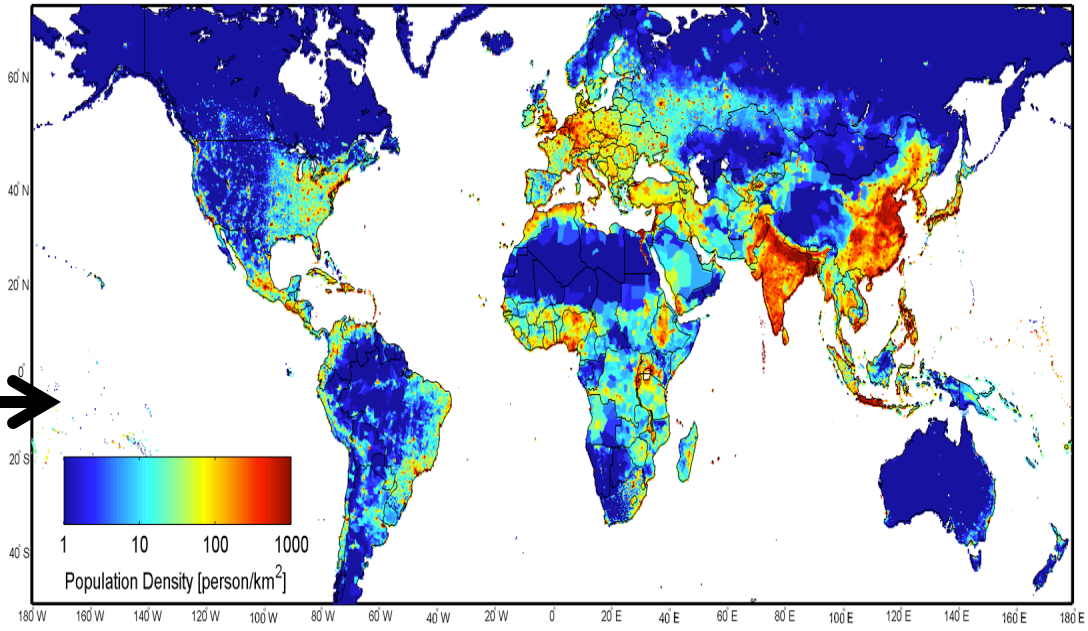


Ground Sensor Network

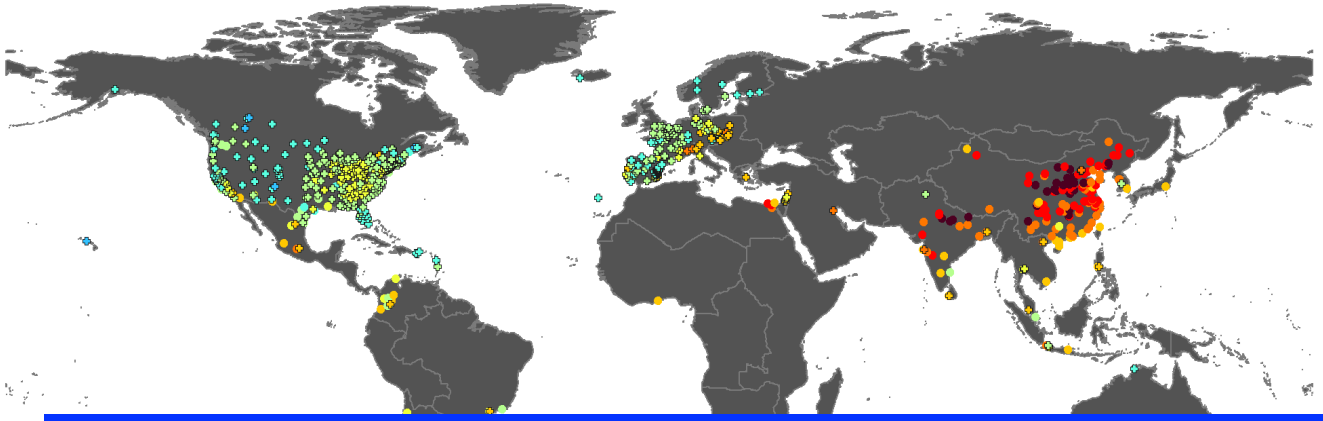


Brauer M, Ammann M, Burnett R et al.
GBD 2010 Outdoor Air Pollution Expert Group
2011 Submitted –under review

Population Density



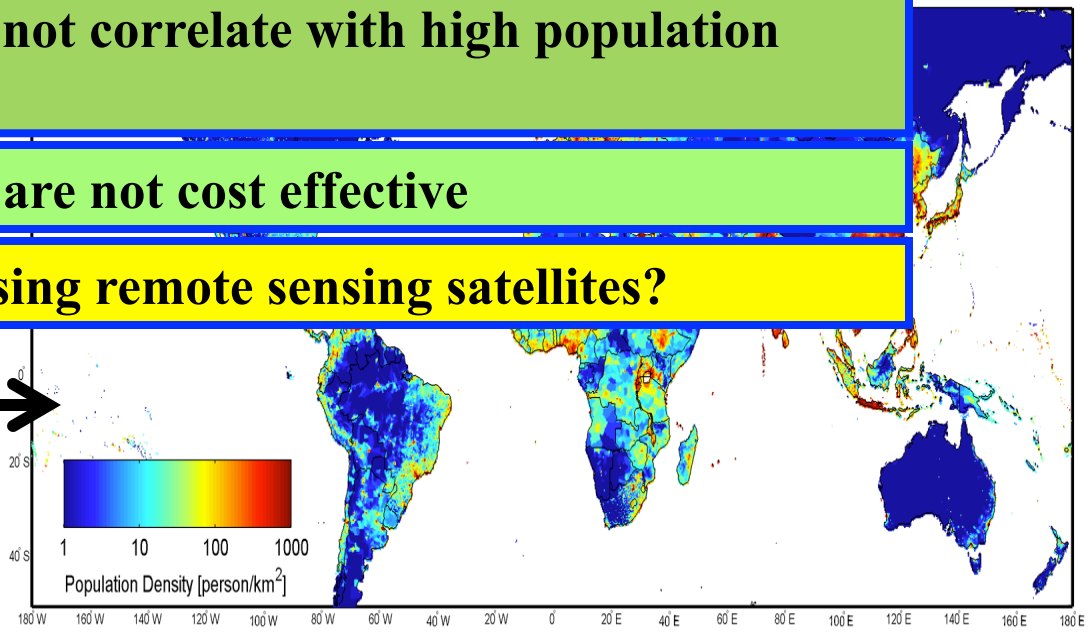
Global Status of PM2.5 Monitoring



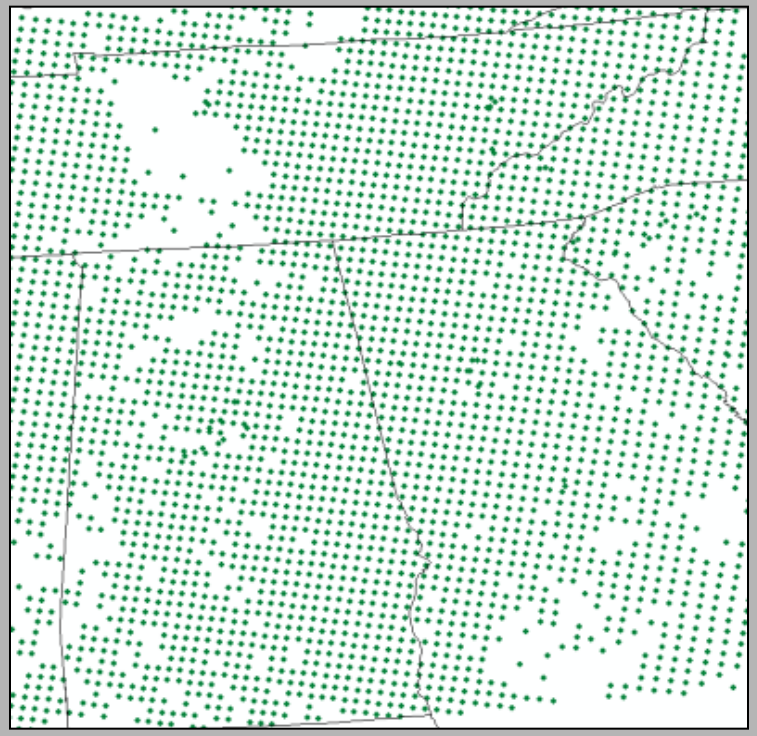
Ground Sensor Network

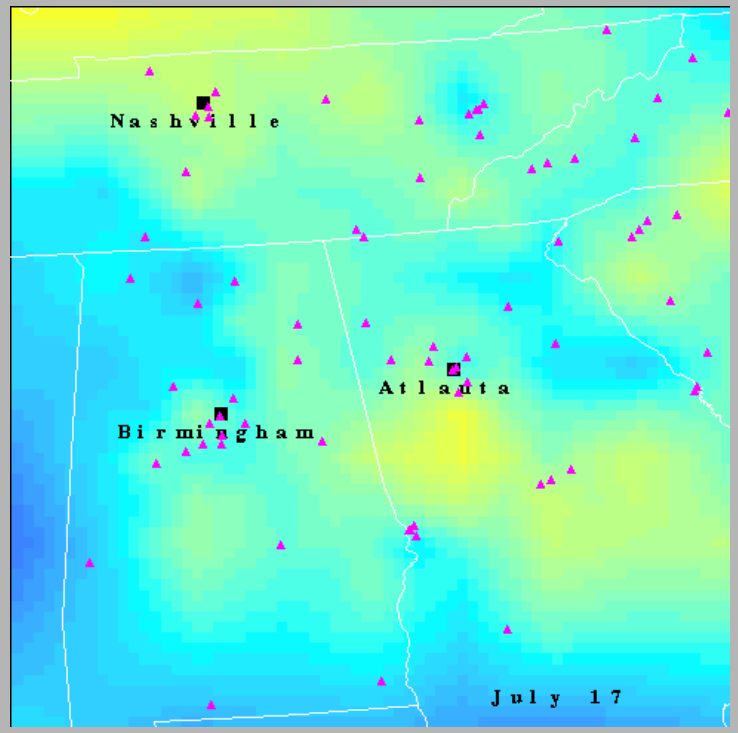
- Many countries do not have PM2.5 mass measurements
- Spatial distribution of air pollution derived from existing ground networks does not correlate with high population density
- Surface measurements are not cost effective
- How about using remote sensing satellites?

Population Density



Why Use Remote Sensing Data?
Spatial Coverage



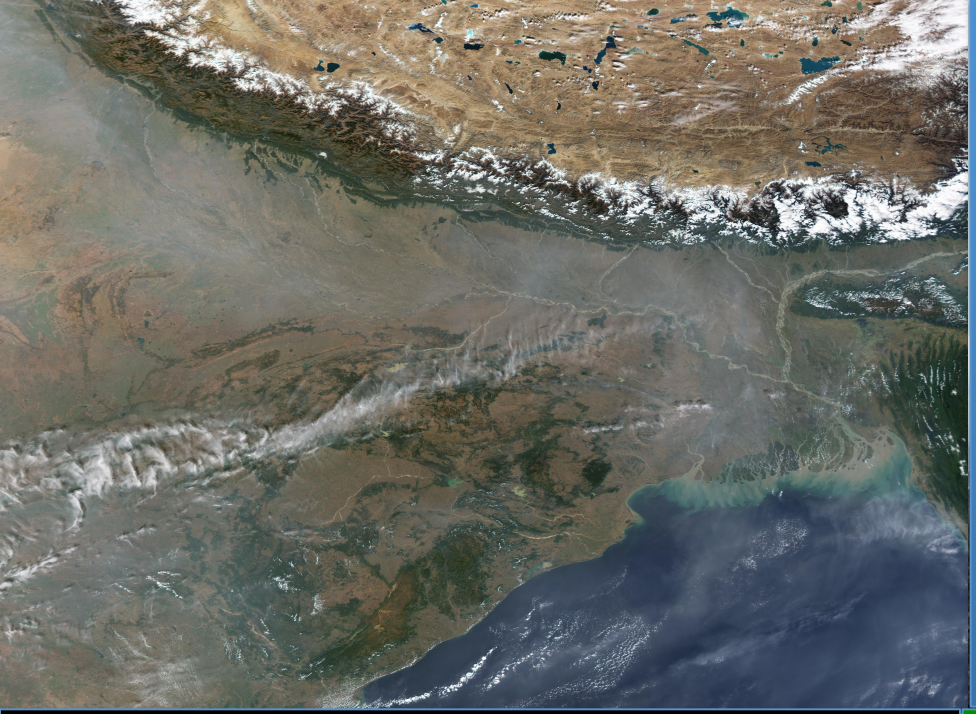


- Satellite (MODIS) Pixel Locations
White Areas – No Data
(Most likely due to clouds)

– Ground Monitors

Particulate Matter

- Aerosols absorb and scatter light.
- Satellites measure the reflected light.
- We estimate total column aerosol.
- Total column aerosol is used to estimate ground levels of PM 2.5.

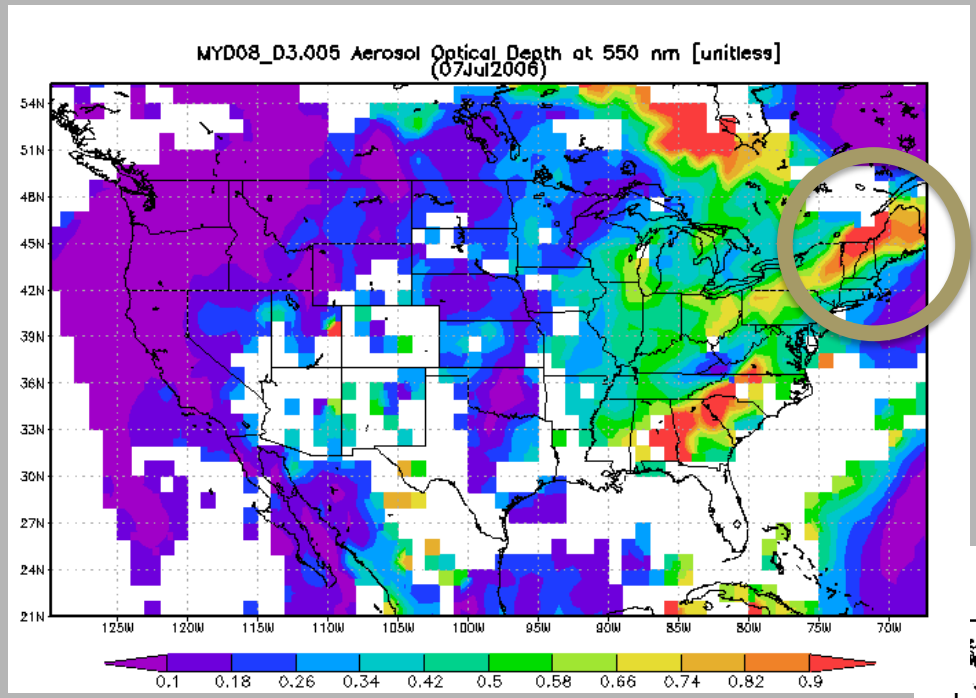


Door #1

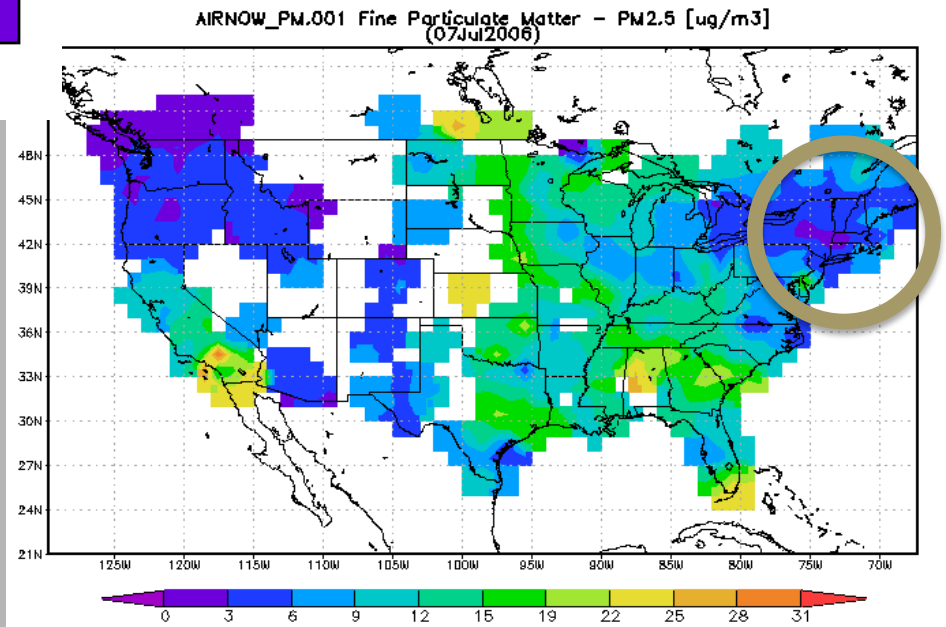
Door #2

Door #3

Satellite measurements are a total column, not always correlated with surface Air Quality !

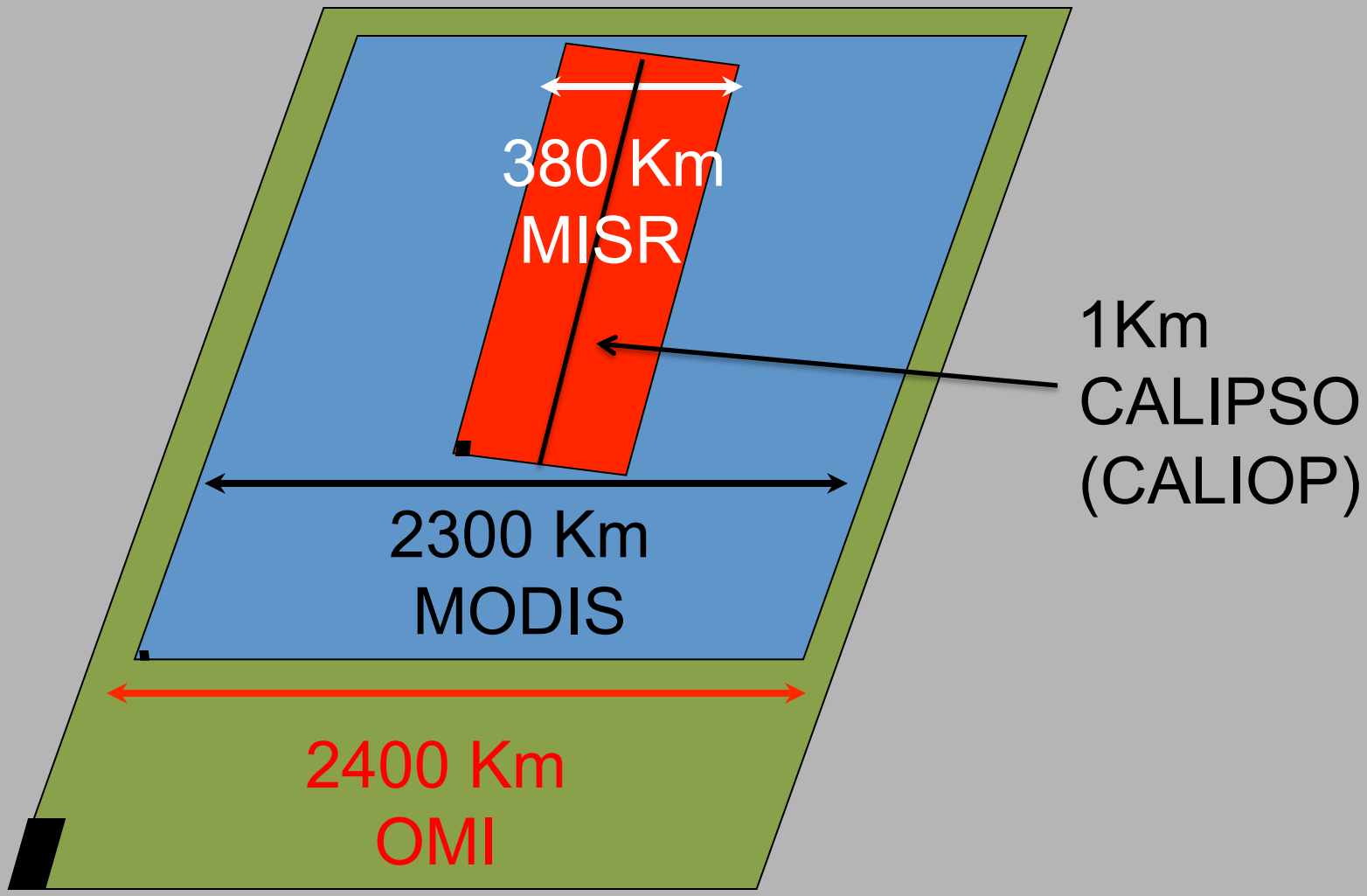


MODIS AOD



AirNOW
PM 2.5

Principal Satellites in Air Quality Remote Sensing



Determining Ground Level Exposure Using Remote Sensing Data

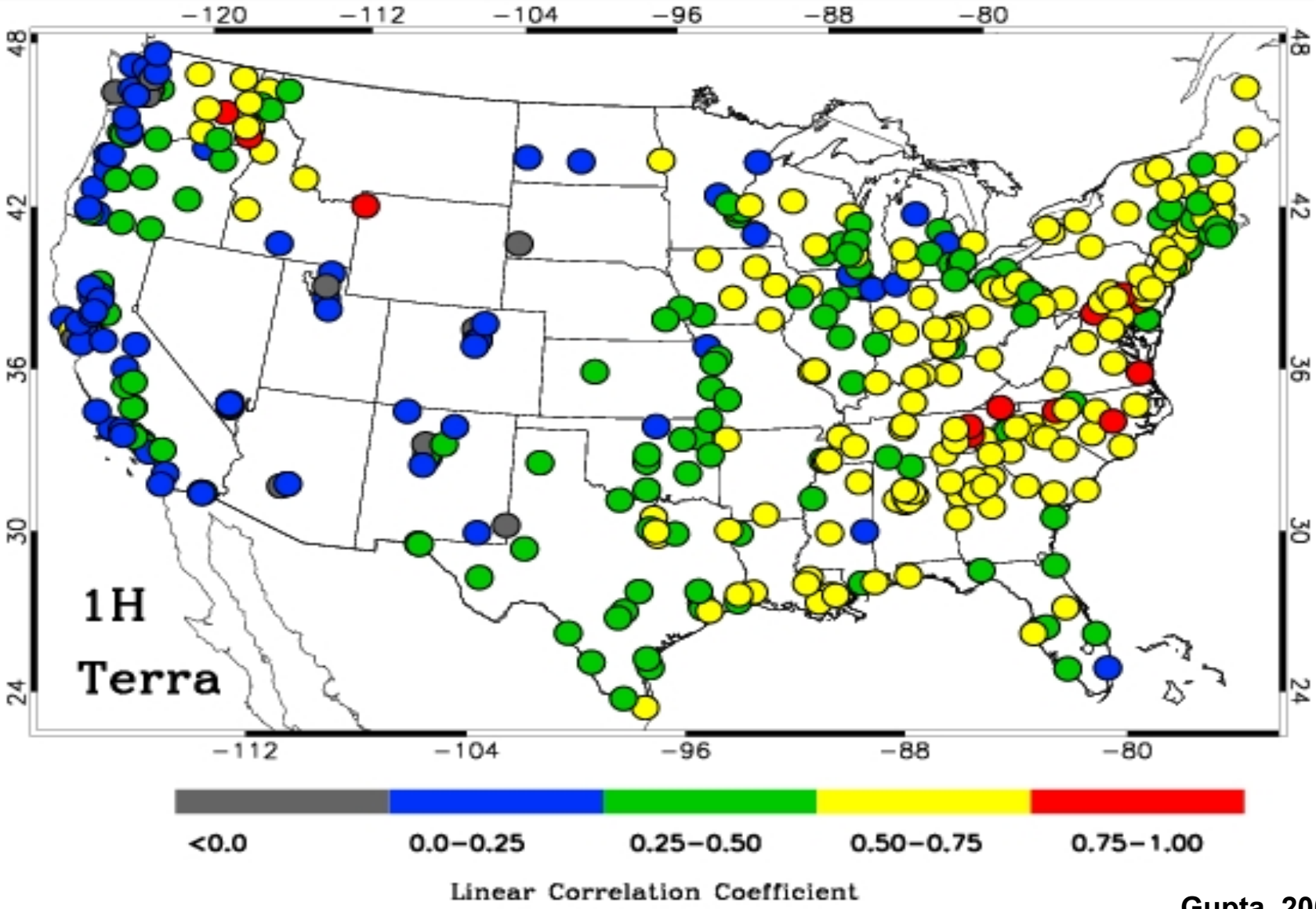
1) Past and current techniques

2) Current and future methods
    a) Long term monitoring
    b) Real time measurements
    c) Air quality forecasting

Historical Methods Relating Satellite AOD and Ground Level PM2.5

Correlations of MODIS and MISR AOD and PM 2.5

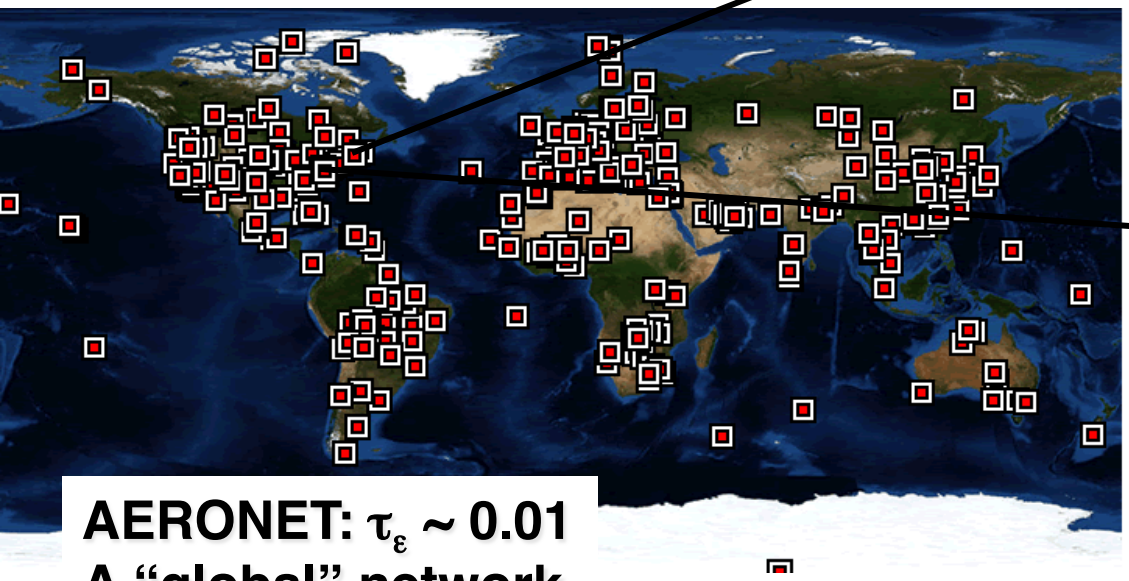
AOT-PM2.5 Relationship



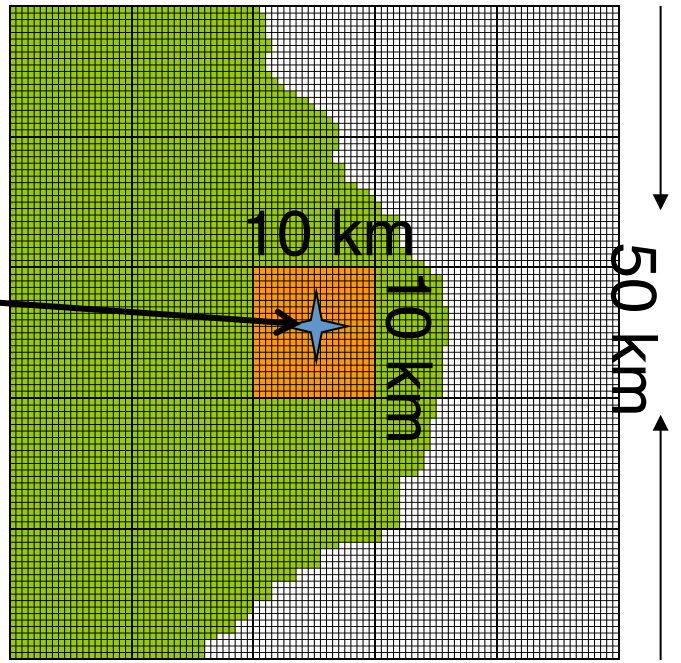
Gupta, 2008

Aerosol Retrieval Evaluation

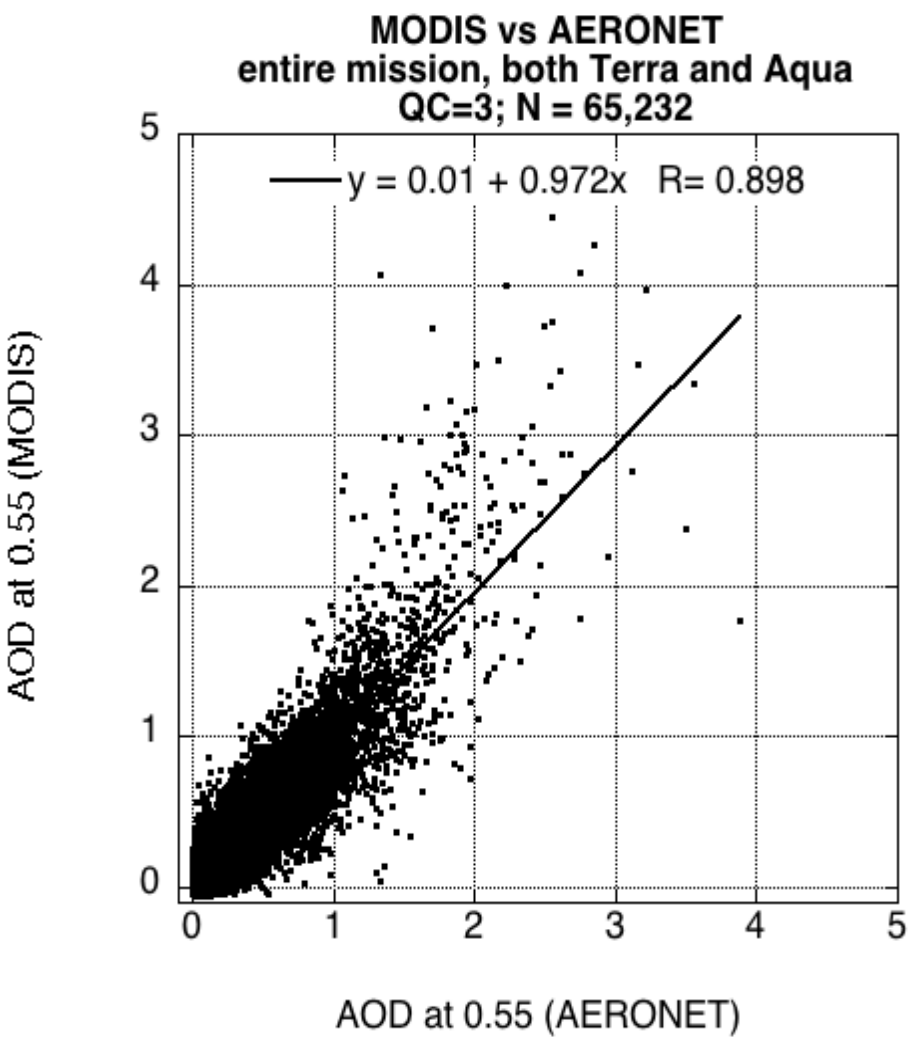
- Self Consistency
  - Visual check
  - No Angle dependency
  - Valid cloud mask
  - Land / Ocean continuity
- Comparison with “ground truth” (e.g. sunphotometer)



AERONET: $\tau_\varepsilon \sim 0.01$
A “global” network

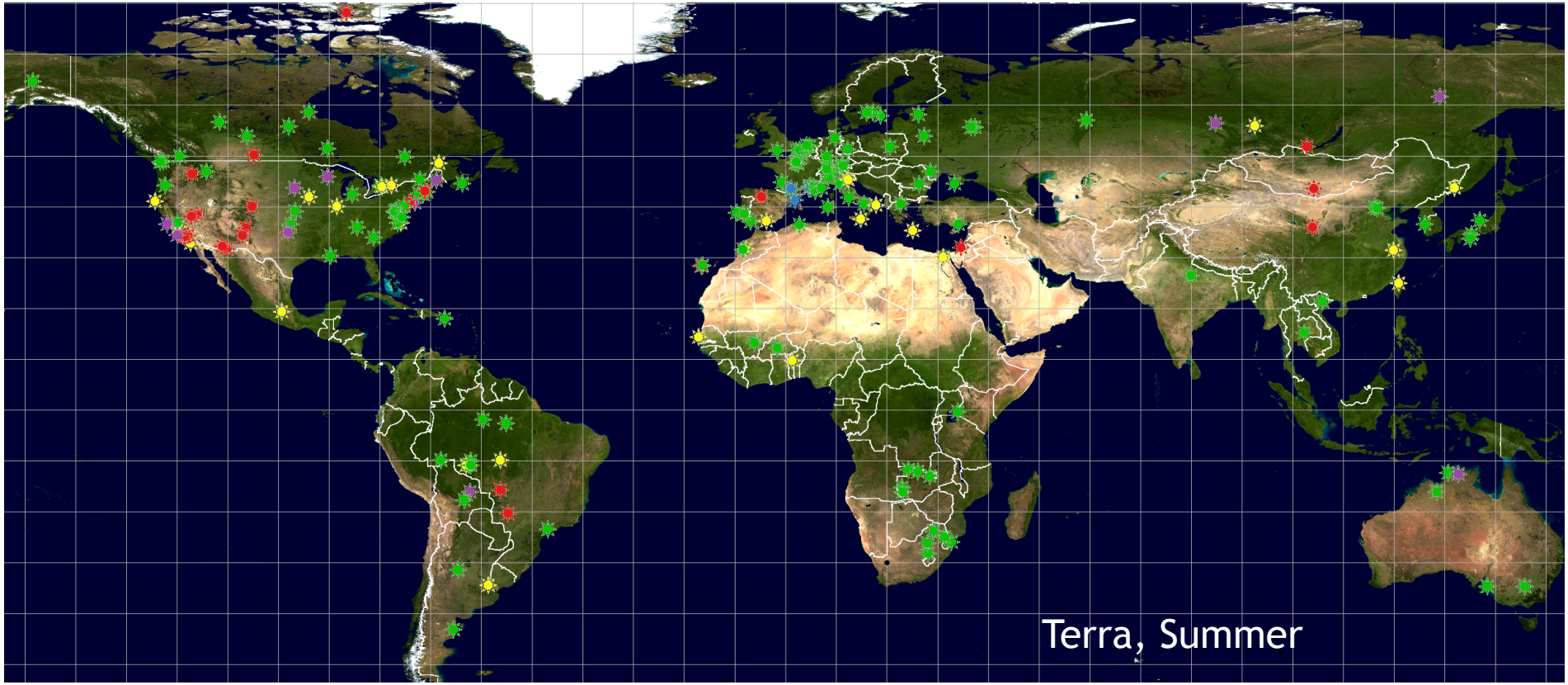


Validation of C005 dark-land $\tau_{0.55\mu m}$



- 50 km x 50 km MODIS versus ±30 minutes AERONET (Ichoku)
- QC = 3 (highest confidence)
- Entire MODIS mission through May 2008. Terra + Aqua
- 72% within expected error of $\pm 0.05 \pm 0.15\tau_{AERONET}$
- No difference between Terra and Aqua
- Correlation strong also for less signal ($\tau < 1$)
- N > 65,000, for 286 sites

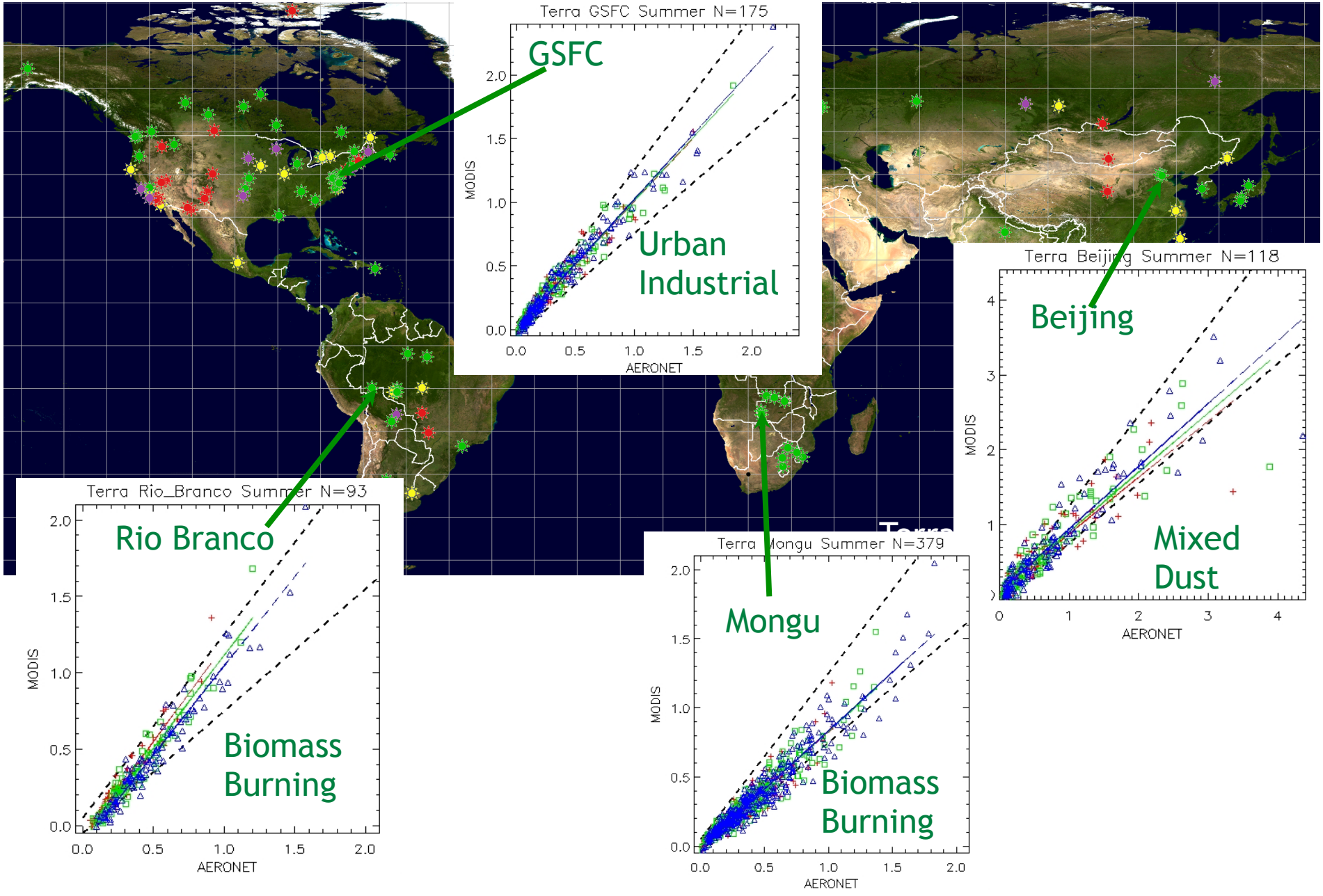
Validation: by satellite, season and site

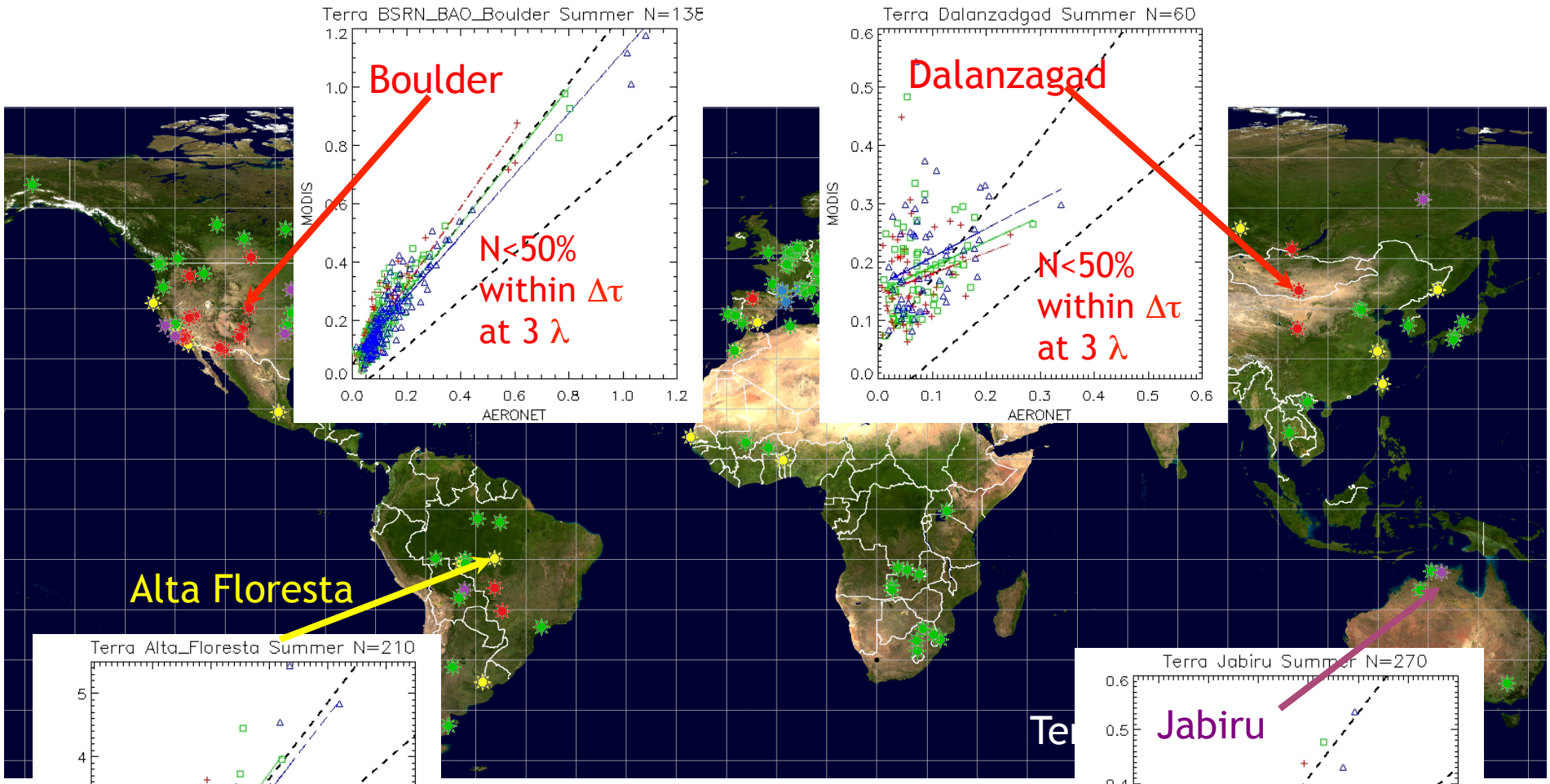


- Easy Quick-look to see how we are doing (compared with sunphotometer)
- Colors represent "quality" of the comparison: Best Worst
- Separate maps per season: DJF MAM JJA SON
- Generally good comparisons in vegetated areas
- Generally poor comparisons over bright and/or elevated targets
- Also GoogleEarth view, where each site is clickable

Most places we do well

>66% within $\Delta\tau$ at 3 λ





Others, not so well (Lots of reasons)

50%<N<66% within Δτ

N>66% at 0.55μm,
N<66% at 0.47μm

Critical Review of Column AOD to Ground PM relationships

Hoff and Christopher, 2009

- Widely varying slopes on this regression
- Seasonal dependence, humidity dependence, **Planetary Boundary Height dependence**, regional dependence
- Error in the slopes lead to propagated error in the $PM_{2.5}$ predictions
- Likely not adequate for regulatory compliance

Courtesy of Ray Hoff, AWMA 39th Critical Review

Some Promising Methods
Using Existing Data

- Combining Global Process Models with Satellite Data

- Combining Statistical Models, Satellite Data and Ground Measurements

- Combining Ground Instruments, Lidar and Satellite Measurements

The Highest Quality of Data Rests on a Tripod

Satellite Data

Ground Measurements and In-Situ Data

Models

Relating Column Measurements and Ground Concentrations

Following *Liu et al.*, 2004:

$$\text{Estimated } PM_{2.5} = \eta \cdot \tau \text{ (AOD)}$$

Some key factors we may need to know to accurately determine η

- **Vertical Structure**
- meteorological effects
- diurnal effects
- **Aerosol mass**
- aerosol type
- humidification of the aerosol

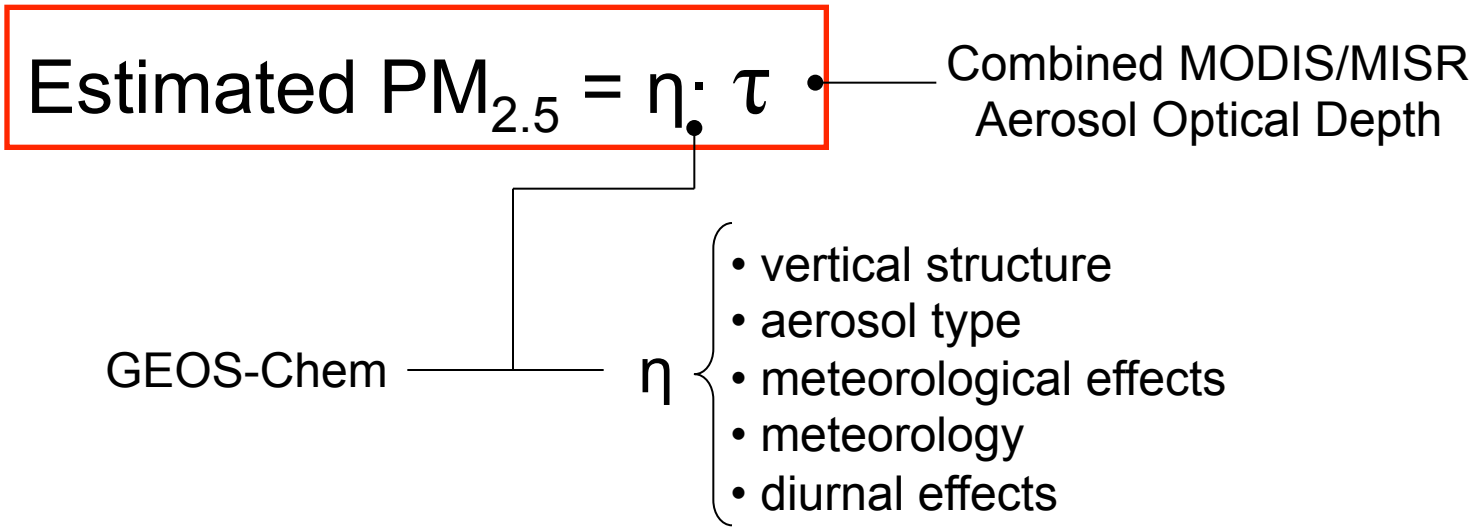
Correlations vary from region to region as do the factors which have the greatest influence on η

Combining Global Process Model and Satellite Observations

Van Donkelaar et al. relate satellite-based measurements of *aerosol optical depth* to $PM_{2.5}$ using a global chemical transport model

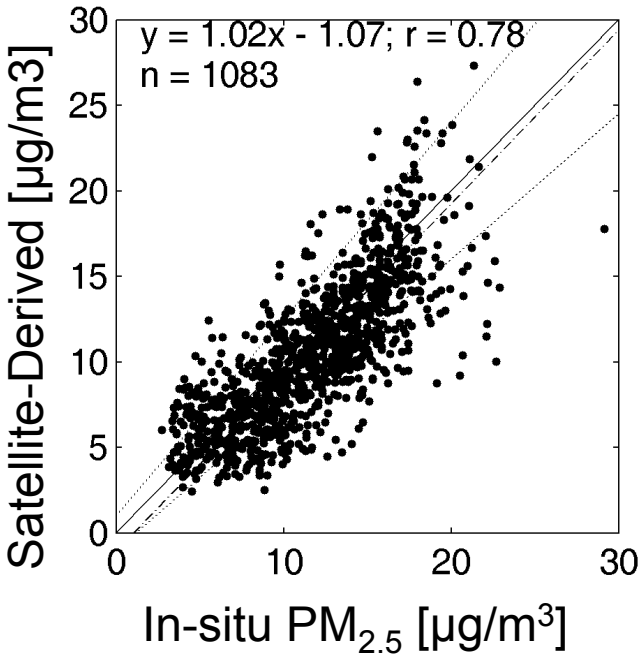
van Donkelaar et al., EHP, 2011

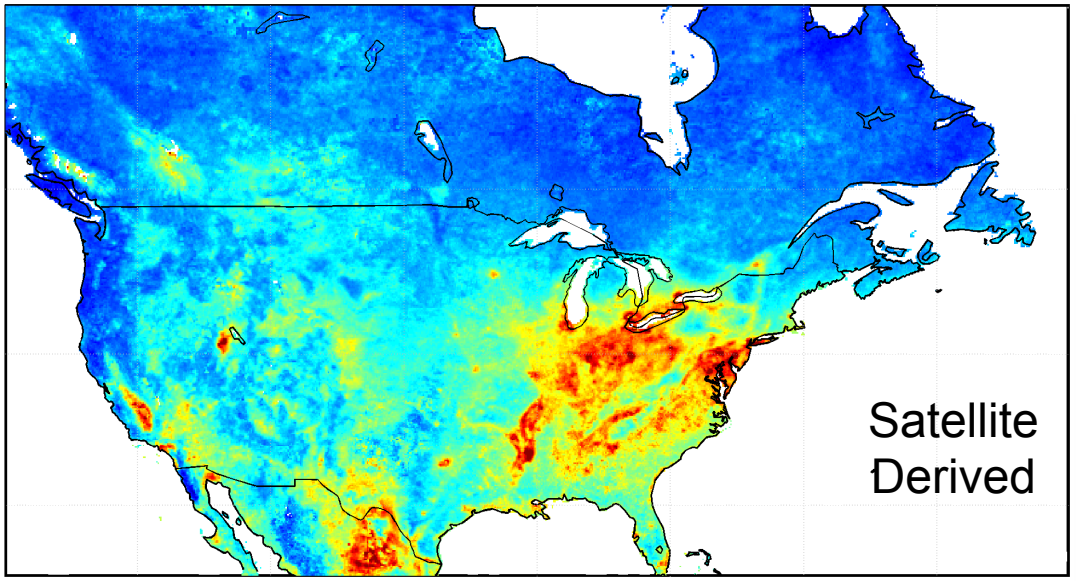
Following *Liu et al.*, 2004:

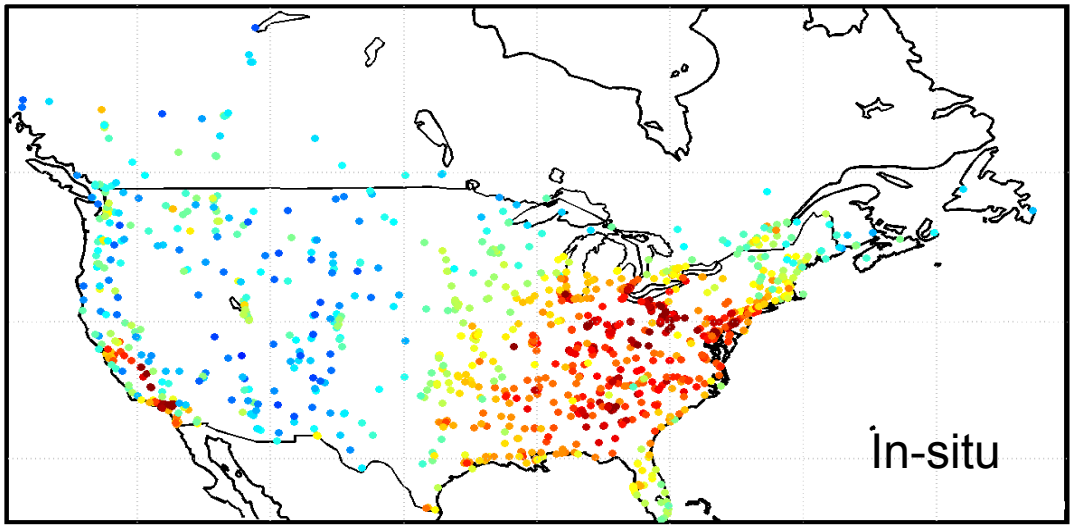


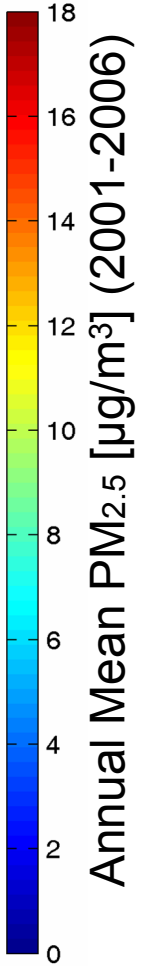
Reasonable agreement with coincident ground measurements over NA

	r
MODIS τ	0.40
MISR τ	0.54
Combined τ	0.63
Combined $PM_{2.5}$	0.78





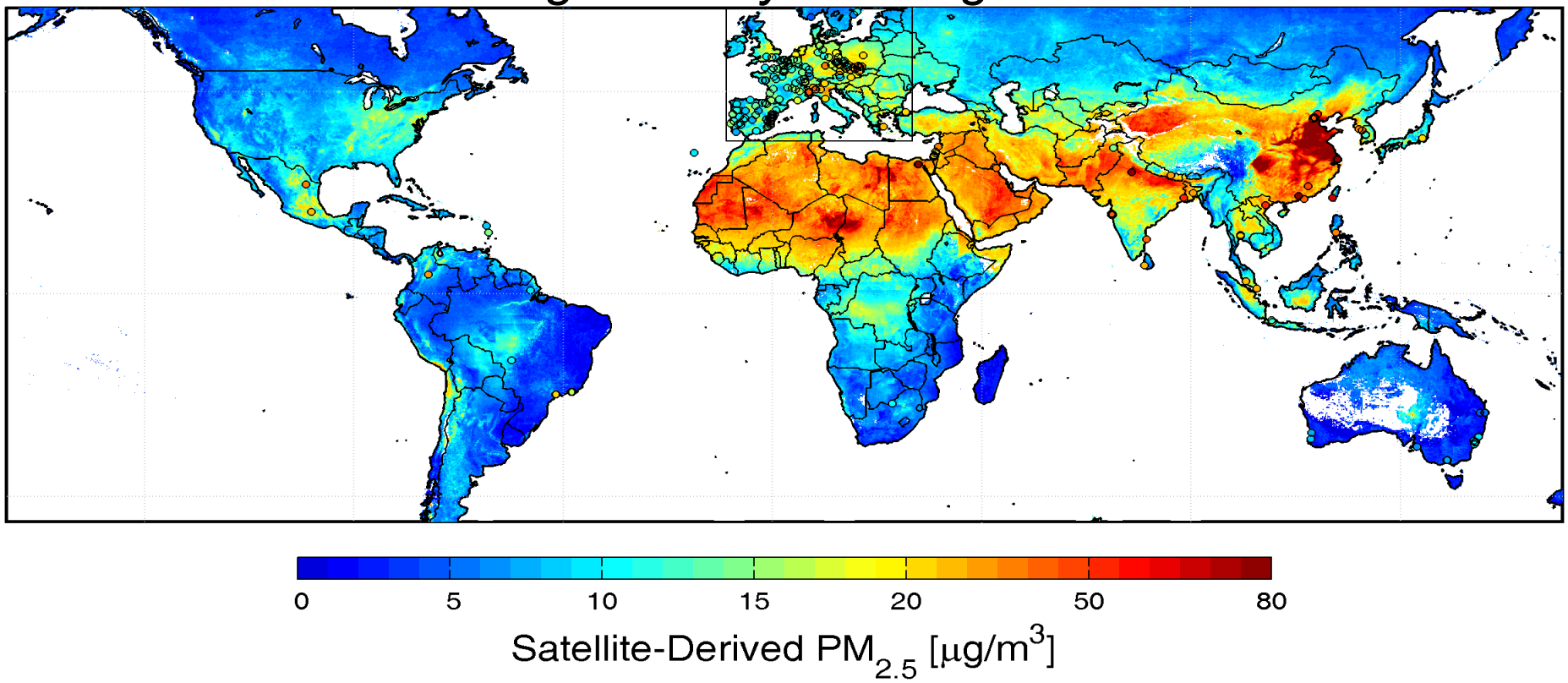




van Donkelaar et. at.

Method is globally applicable.

It is important to note that model performance can vary significantly with region



- Annual mean measurements
  - Outside Canada/US
  - 244 sites (84 non-EU)

- r = 0.83 (0.91)
- slope = 0.86 (0.84)
- bias = 1.15 (-2.52) $\mu g/m^3$

van Donkelaar et. at.

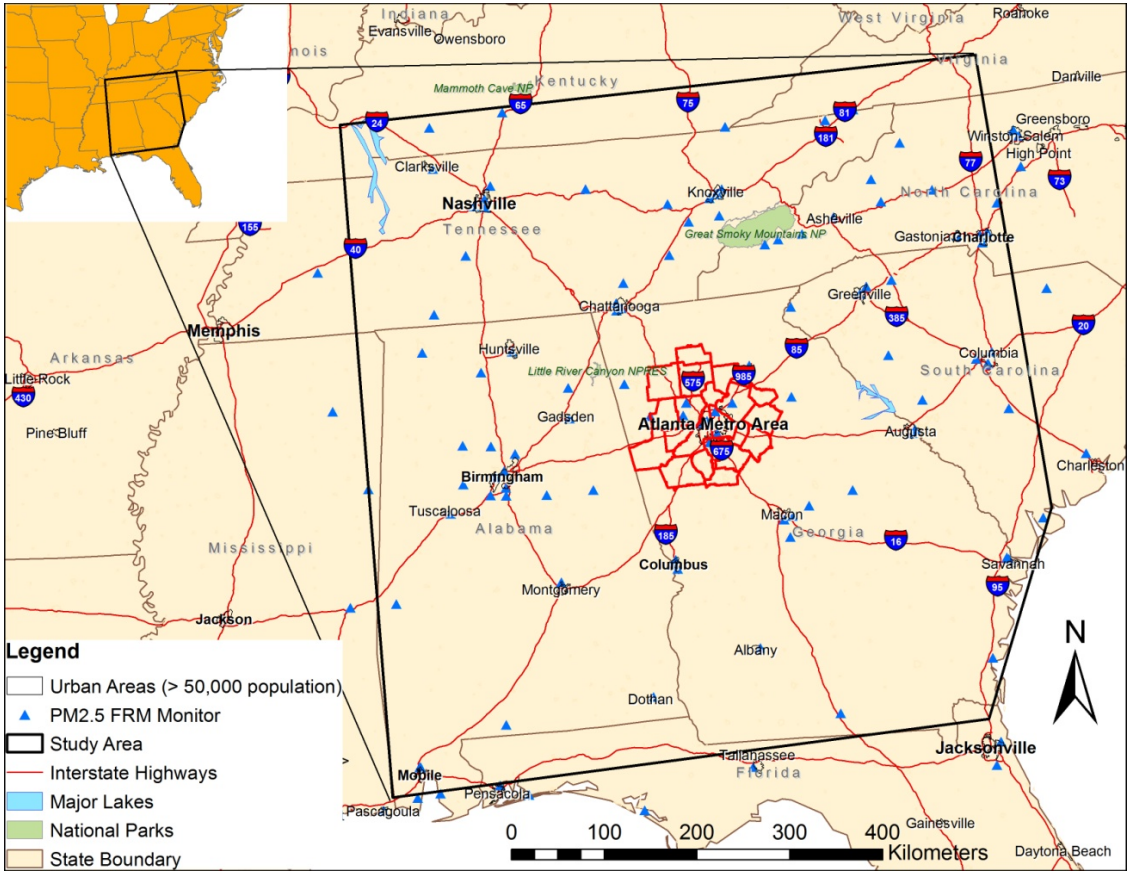
Combining Statistical Models, Satellite Data and Ground Measurements

Creating Daily MODIS Correlation Maps Using PM2.5 Measurements
Lee et. al. Harvard School of Public Health

- Can be applied to any region

- Results can be used to improve daily correlations

Recent work by Yang Liu at Emory University
Using a statistical model to predict annual exposure

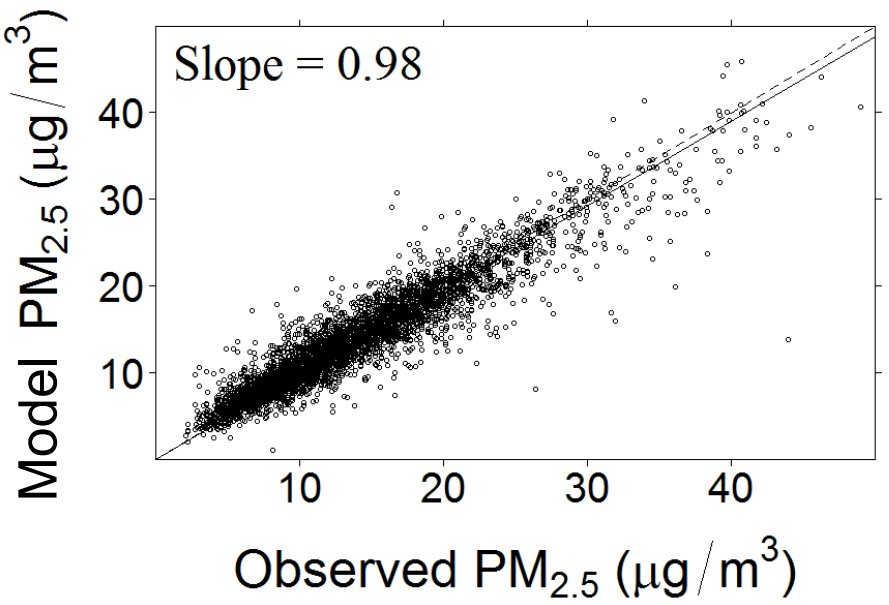


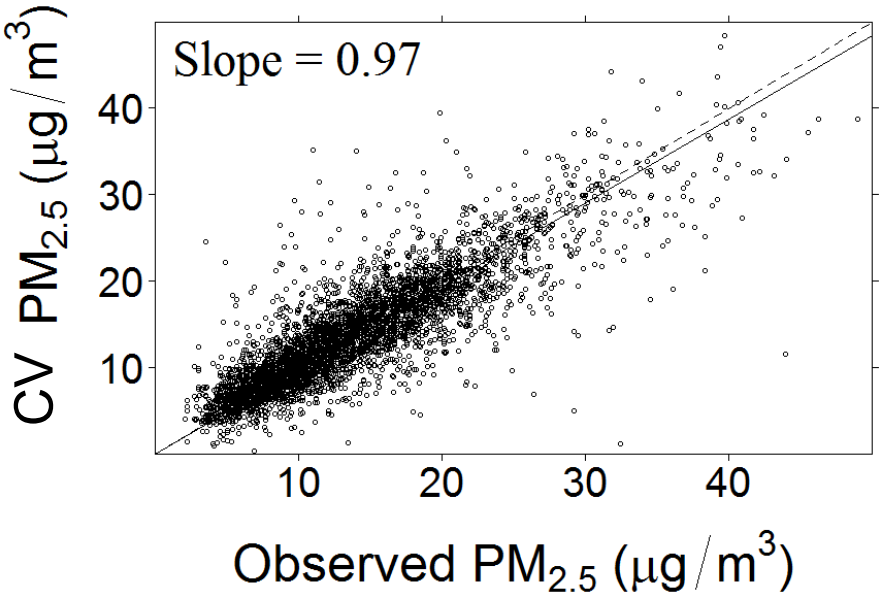
- Number of monitoring sites: 119
- Exposure modeling domain: 700 x 700 km^2

Model Performance Evaluation

	Mean	Min	Max
Model R^2	0.86	0.56	0.92
CV R^2	0.70	0.22	0.85

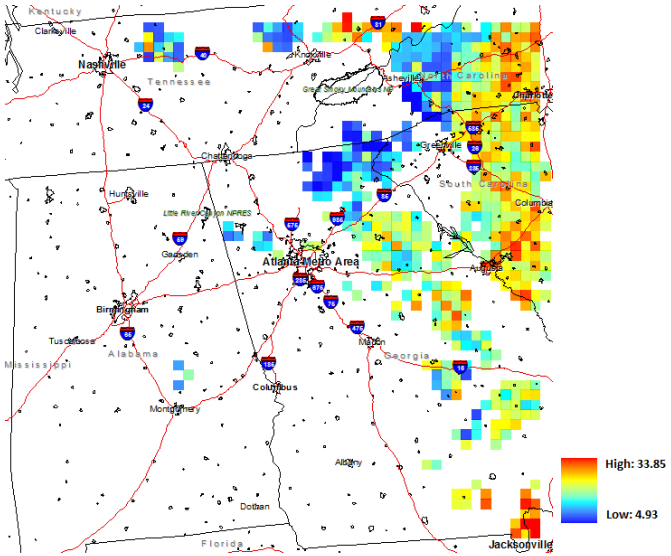
Putting all the data points together, we see unbiased estimates



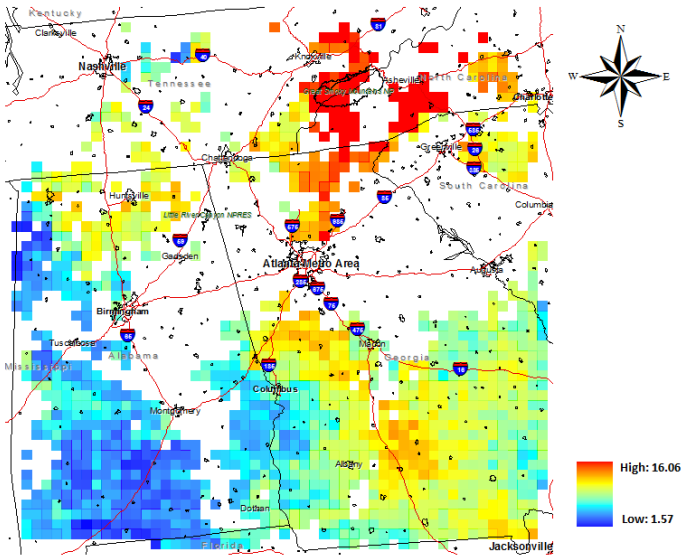


Predicted Daily Concentration Surface

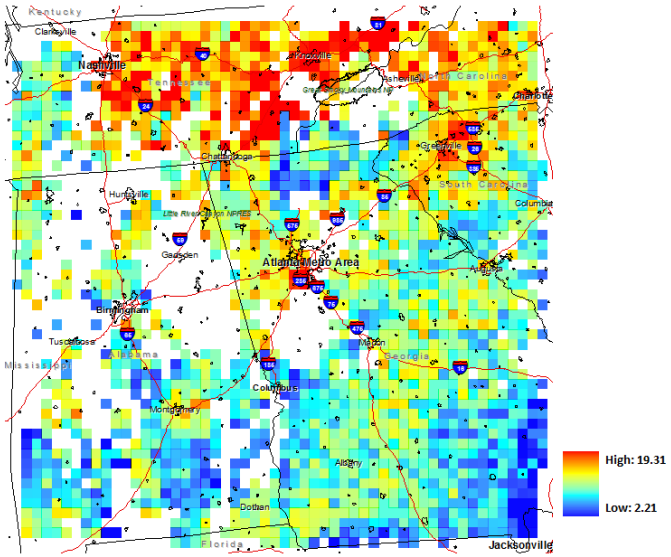
Day: 264 (Record: 549)



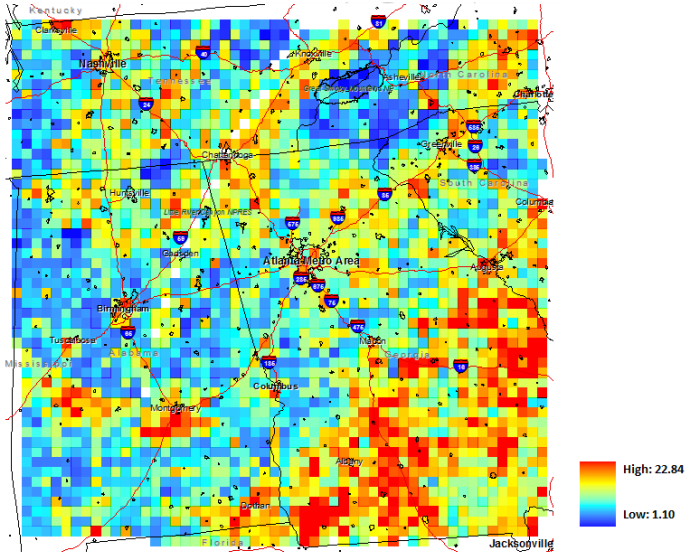
Day: 165 (Record: 1387)



Day: 225 (Record: 2069)

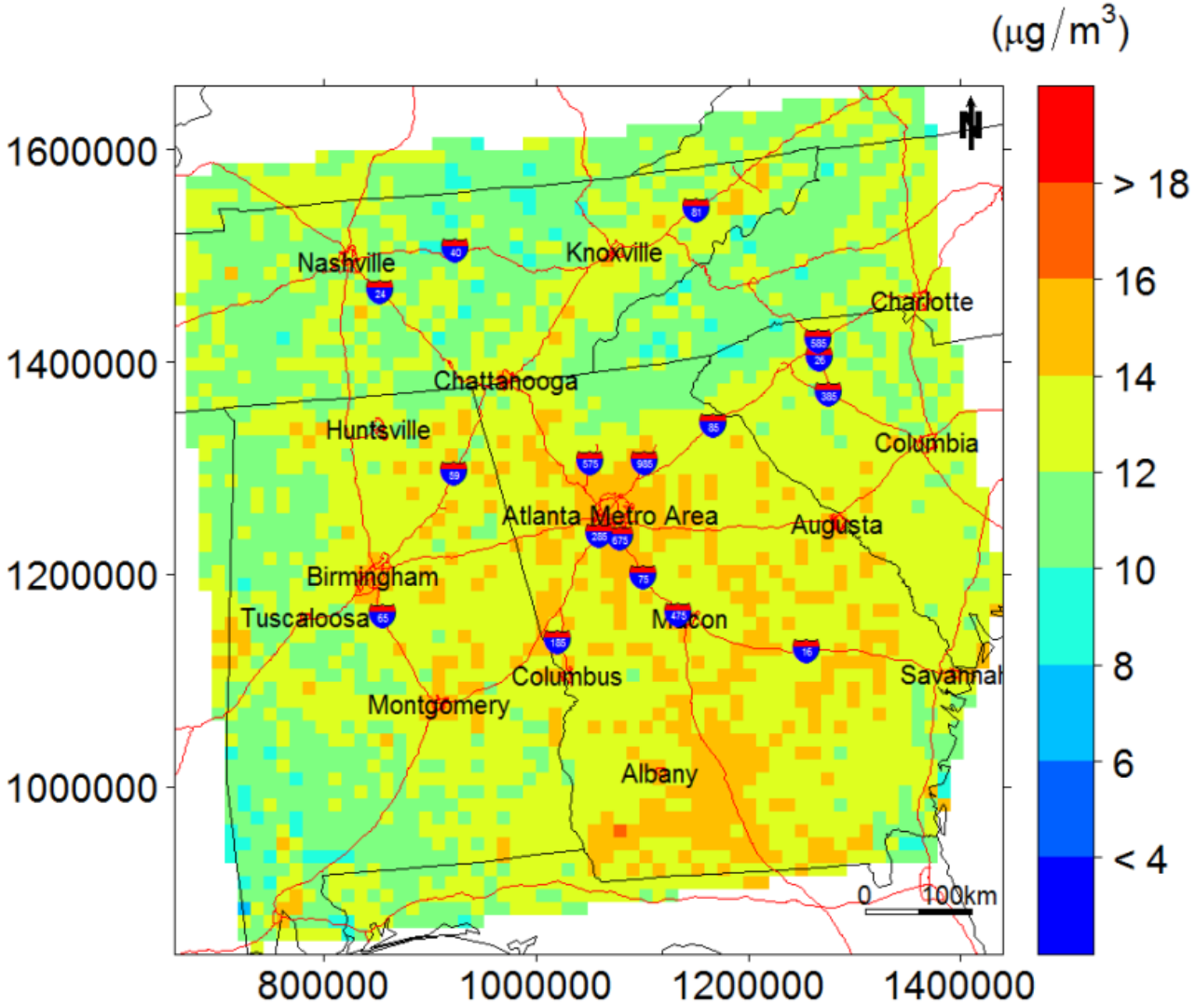


Day: 360 (Record: 2774)



0 60 120 240 360 480 Kilometers

Model Predicted Mean $PM_{2.5}$ Surface



Note: Annual mean calculated with137 days

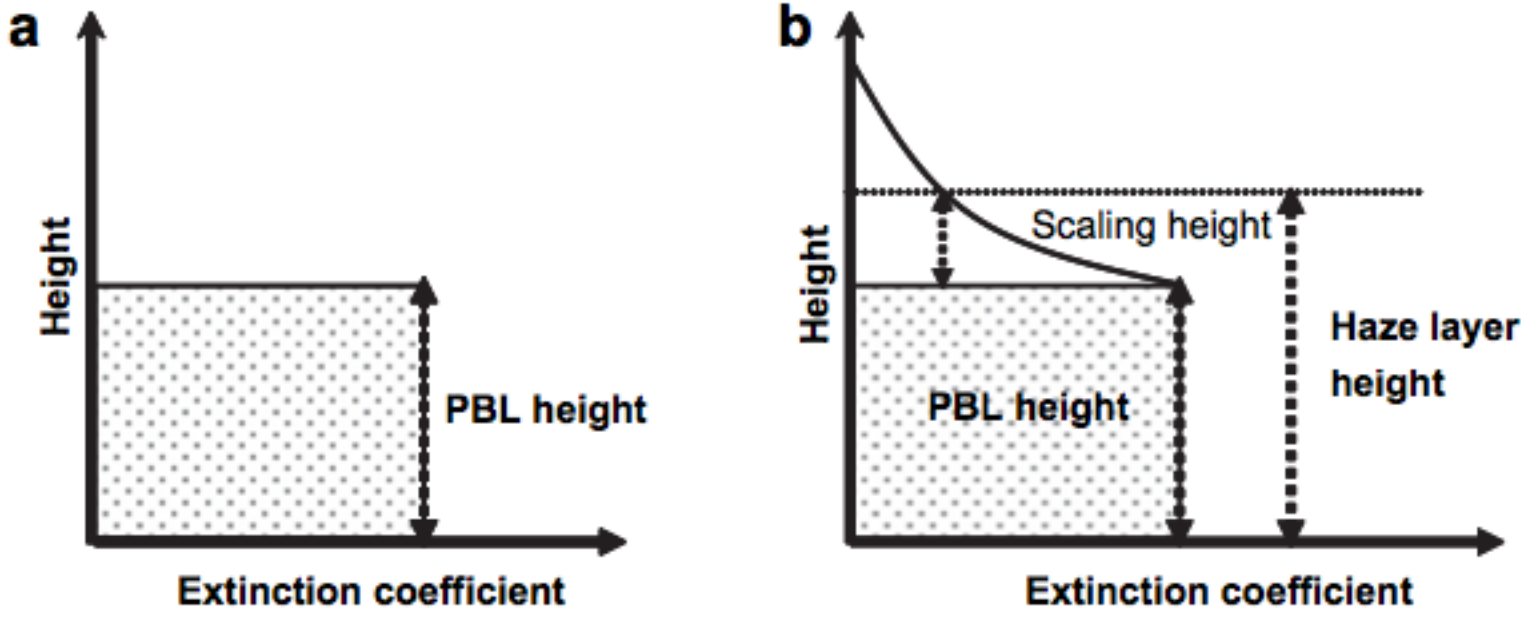
Using Coincident Ground Based Data, Lidar, and Satellite Measurements.

Analysis of the relationship between MODIS aerosol optical depth and particulate matter from 2006 to 2008

Tsai et. al. 2011

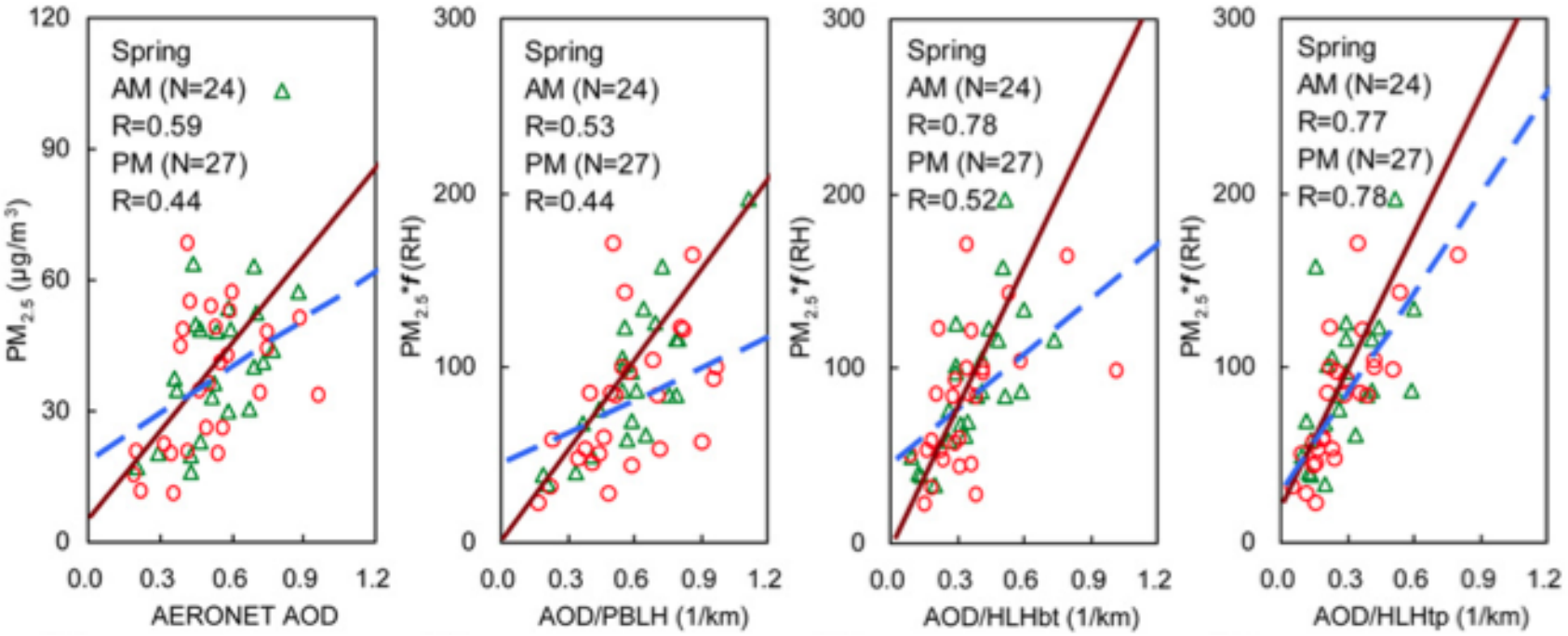
Atmospheric Environment

Lidar is used to identify the
(a) Planetary boundary layer (PBL)
(b) Haze layer. Elevated layer above the PBL



Haze layer
Bottom to Top

Haze layer
Top to Bottom



PM2.5 vs. AOD

PM2.5*f(RH)
vs. AOD/PBLH

PM2.5*f(RH)
vs. AOD/HLHbt

PM2.5*f(RH)
vs. AOD/HLHtp

Triangles indicate Terra data and circles indicate Aqua data.
Solid and dashed lines represent the linear regressions of AM and PM
of sunphotometer AOD corresponding to Terra and Aqua overpasses, respectively.

Method Application

- Combining Global Process Models with Satellite Data

  Annual and Seasonal

- Combining Statistical Models, Satellite Data and Ground Measurements

  Daily Prediction, Annual Calculations

- Combining Ground Instruments, Lidar and Satellite Measurements

  Seasonal Calculations

Steps Which Can Be Taken to Improve Remote Sensing-$PM_{2.5}$ Correlations

- Tuning the Satellite AOD retrieval to local conditions.
- Use of transport, forecast, numerical and statistical models.
- Use of additional satellite aerosol and trace gas data.
- Ground instrument networks for creating daily AOD – PM relationships
- Use of ground and space borne lidars for vertical resolution of aerosols and boundary layers
- Local meteorological data

NASA Earth Science Division Operating Missions

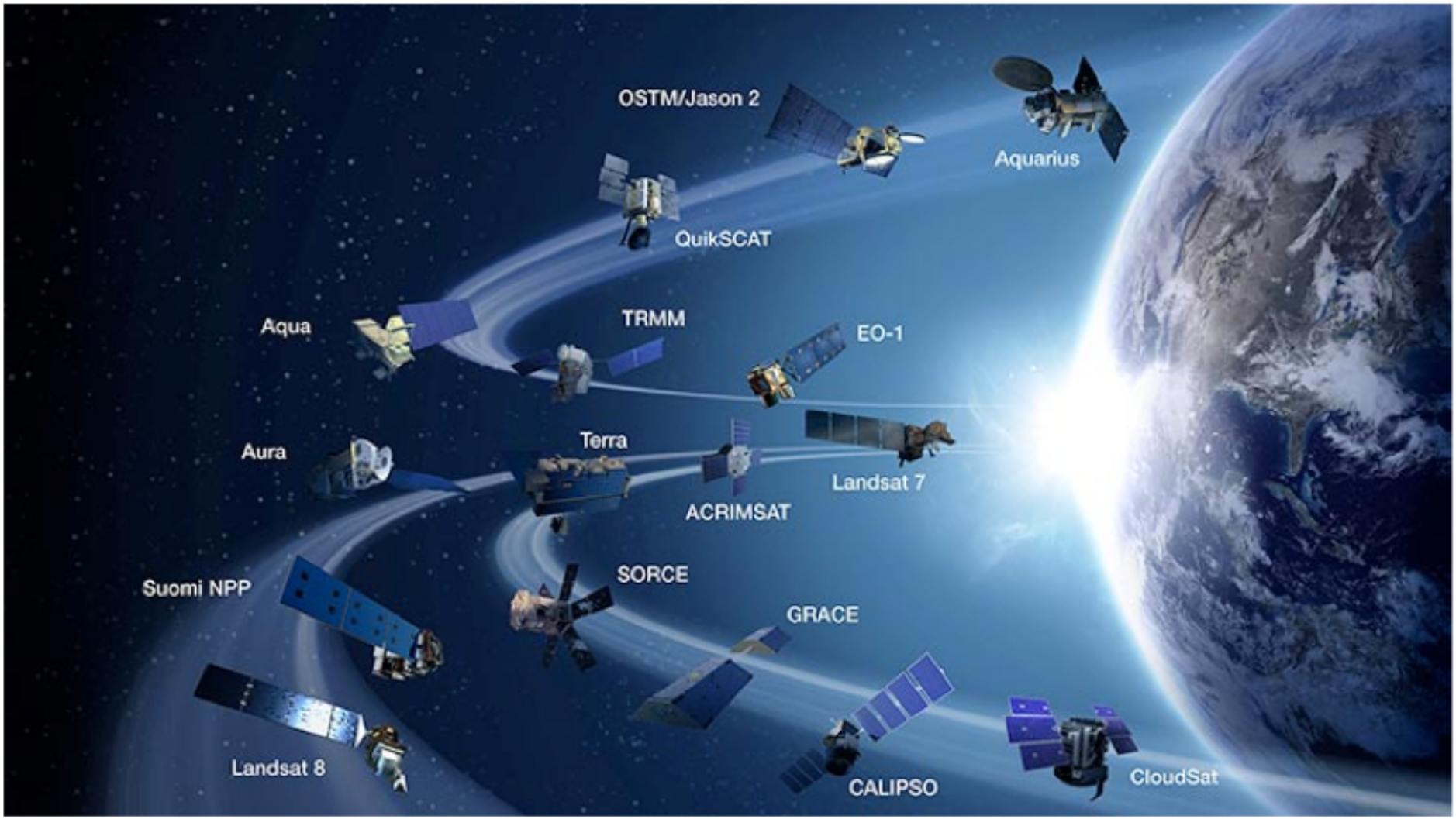


Image by Jenny Mottar, NASA Headquarters
Added: July 1, 2013

Current and Future Prospects Satellite Data

Several New Missions in Development

Recent Launch of VIIRS

Products are improving spatial resolution.

Near future launch of geosynchronous satellites will improve temporal resolution

Several Missions Beyond Design Life

Loss of Main Vertical Resolving Sensor

National Aeronautics and Space Administration
Goddard Space Flight Center

Search

Flight Projects | Sciences and Exploration

http://aura.gsfc.nasa.gov

Aura atmospheric chemistry

The Aura Mission | Science and Data | Education and Outreach | Stratospheric Ozone | Air Quality

- What's New?
- About the Mission
- Why Aura?
- Spacecraft and Instruments
- Ground Operations
- Meet the Team
- Newsroom

Prev

Next

Aura's Ozone Monitoring Instrument (OMI) instrument show long tracks of elevated nitrogen dioxide (NO_2) levels along certain shipping routes.

1 2 3 4 5 6 7

Latest from Aura : Science Features I Full Newsroom

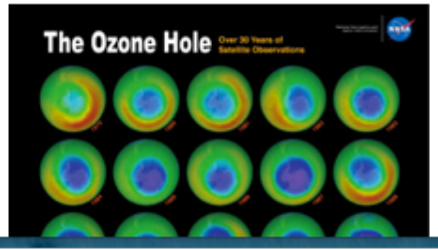
Announcements

REEL Science Communications Contest Winners Announced
+ Congratulations to this year's winners!

EOS Aura Science Team Meeting October 1-3, 2012 . Pasadena, CA
+ Agenda and Presentations
+ Poster Abstracts I + Oral Abstracts

How NASA keeps tabs on air pollution from space

The Ozone Hole : Over 30 years of NASA Observations



National Aeronautics and Space Administration
Goddard Space Flight Center

Search

Flight Projects | Sciences and Exploration

http://npp.gsfc.nasa.gov

POLAR-ORBITING MISSIONS

Select Mission | Science and Data | The Instruments | Resources | Newsroom

Suomi-NPP
National Polar-orbiting Partnership

JPSS
Joint Polar Satellite System

TCTE
Mission

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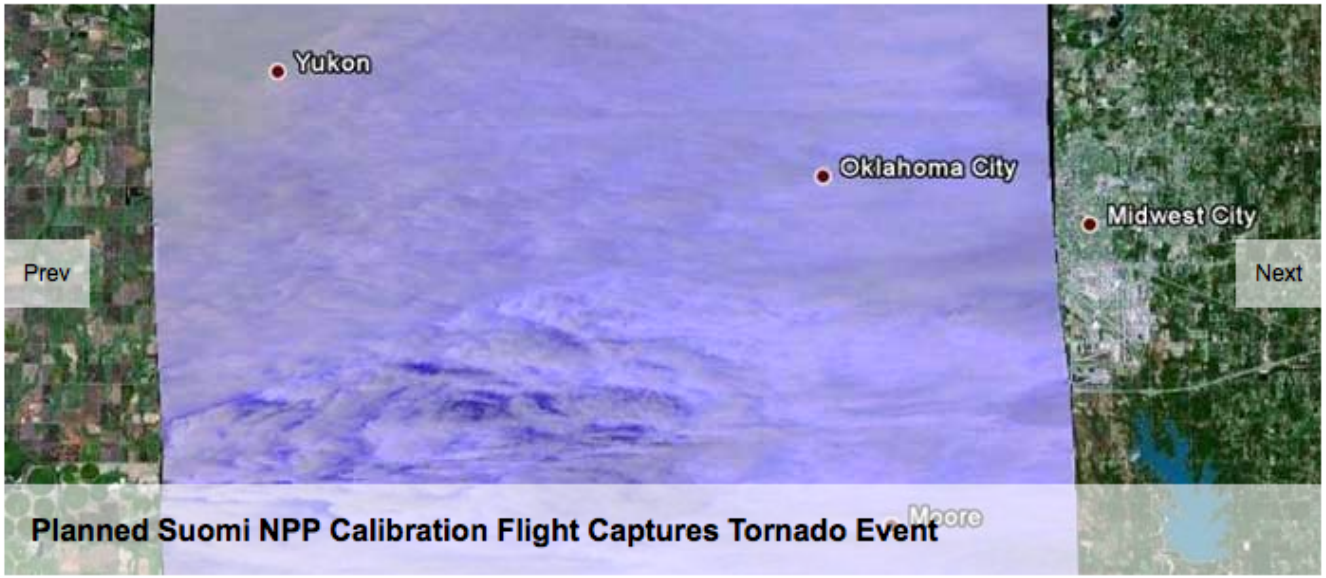


Planned Suomi NPP Calibration Flight Captures Tornado Event

Newsroom | Science Observations

1 2 3 4 5 6 7 8 9 10

Mission Updates/Announcements

07.15..2013 - Science Documents Updated

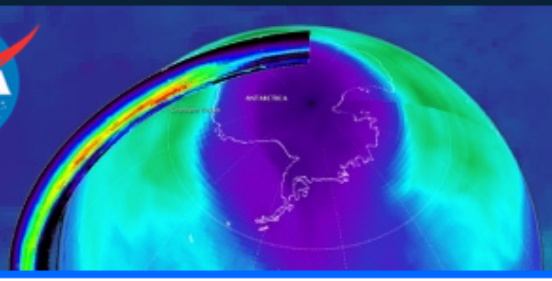
Tweets Follow

Suomi NPP Satellite 5 Feb

Ozone Mapper Profile Suite (OMPS)

http://npp.gsfc.nasa.gov/omps.html

- Launched October 28, 2011 on-board the Suomi NPP satellite.
- OMPS is the next generation OMI instrument and will continue to extend the total ozone record, past the lifetime of OMI.
- The main purpose is to measure global distribution of ozone in the stratosphere.
- Includes a Limb profiler to measure vertical structure of stratosphere ozone ONLY from 15 km to 60 km.
- Aerosol Index (AI) and SO_2 data will also be provided.
- Data only available to the Science Team.



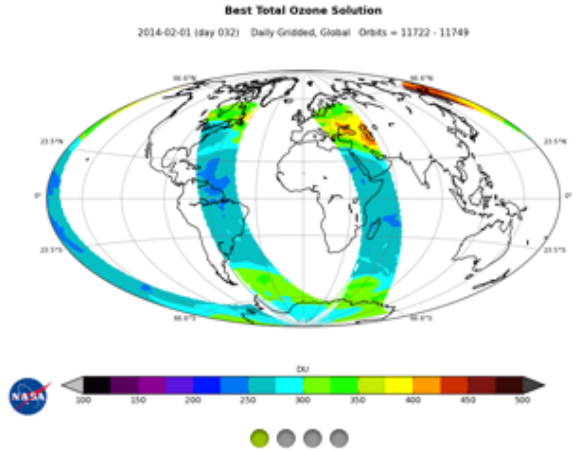
Suomi National Polar-orbiting Partnership

OMPS

Ozone Mapping & Profiler Suite

Measuring global ozone, aerosols, and reflectivity.

Nadir: Total Ozone



Limb: Ozone Curtain Plot (orbital)

Previous Orbit Next Orbit

http://ozoneaq.gsfc.nasa.gov/omps

Latest News

29 JAN

Latest Air Quality Over Asia

I seem to be posting a lot about air quality over Asia these days, but I find the imagery compelling ...

27 JAN

Second Anniversary of OMPS "First Light" Data

Happy Anniversary! I just realized that today is the second anniversary of "first-light" measurements from OMPS (actually, yesterday was, although ...

27 ...

Air Quality Over Asia

Interesting article in the New York Times about air quality

Highlights

12/12/13 -- NASA Reveals New Results From I...

10/26/13 -- OMPS Sees SO2 From Kliuchevsko...

08/14/13 -- Around the World in Four Days:...

04/04/13 -- SNPP-OMPS data takes its place i...

Read more on the blog...

OMPS

This is a portal to SDR (Level 1), EDR (Level 2), and gridded (Level 3) research products generated by NASA's NPP Ozone Science Team.

Data

- OMPS Nadir Mapper - TC_EDR_TO3
- OMPS Nadir Mapper - TC_EDR_TO3_L3Daily_UVAerosolIndexAscii
- OMPS Limb Profiler - LP_ANC_EV_GRID
- OMPS Limb Profiler - LP_SDR_EV_GRID

Imagery

- OMPS Limb Profiler - LP_EDR_ORBITAL_PLOT_O3_curtain_plot
- OMPS Nadir Mapper - TC_EDR_TO3_L3Daily_UVAerosolIndex
- OMPS Nadir Mapper - TC_EDR_TO3_L3Daily_Reflectivity331
- OMPS Nadir Mapper - TC_EDR_TO3_L3Daily_Ozone

Start 2012-07-05 **End** 2012-07-05 Search

Ctrl-click (Windows and Linux) or cmd-click (Mac) to deselect or to select multiple product types.

NOTICE! We do not anticipate releasing V1 LP EDR data after Nov 26, 2013. Data after that date will be processed in Version 2, available early next year. Users needing post-November data before this should contact the OMPS team directly.

Found 110 products. Approximately 2.9 GB uncompressed.

Download as Zip

Date	Measurement Type	Filename
2012/07/05 23:24:57	TC_EDR_TO3	OMPS-NPP-TC_EDR_TO3-v1.0-2012m0705t232457-o03570-2012m12…
2012/07/05 23:24:57	LP_ANC_EV_GRID	OMPS-NPP-LP_ANC_EV_GRID-v1.0-2012m0705t232457-o03570-201…
2012/07/05 23:24:57	NP_SDR_EV_NASA	OMPS-NPP-NP_SDR_EV_NASA-p000-v1.0-2012m0705t232457-o035…
2012/07/05 23:24:57	TC_SDR_EV_NASA	OMPS-NPP-TC_SDR_EV_NASA-p000-v1.0-2012m0705t232457-o035…
2012/07/05 23:24:57	NP_EDR_PV8	OMPS-NPP-NP_EDR_PV8-v1.0-2012m0705t232457-o03570-2012m12…
2012/07/05 23:24:57	NP_SDR_EV_NASA	OMPS-NPP-NP_SDR_EV_NASA-p999-v1.0-2012m0705t232457-o035…
2012/07/05 23:24:57	LP_SDR_EV_GRID	OMPS-NPP-LP_SDR_EV_GRID-v1.0-2012m0705t232457-o03570-201…
2012/07/05 21:43:27	NP_EDR_PV8	OMPS-NPP-NP_EDR_PV8-v1.0-2012m0705t214327-o03569-2012m12…
2012/07/05 21:43:27	LP_SDR_EV_GRID	OMPS-NPP-LP_SDR_EV_GRID-v1.0-2012m0705t214327-o03569-201…

2012/07/05 01:25:30	TC_SDR_EV_NASA	OMPS-NPP-TC_SDR_EV_NASA-p000-v1.0-2012m0705t012530-o03557-2012m1210t19…
2012/07/05 01:25:30	NP_EDR_PV8	OMPS-NPP-NP_EDR_PV8-v1.0-2012m0705t012530-o03557-2012m1211t120721.h5
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2012/07/05 01:25:30	TC_EDR_TO3	OMPS-NPP-TC_EDR_TO3-v1.0-2012m0705t012530-o03557-2012m1217t190804.h5
2012/07/05 00:00:00	TC_EDR_TO3_L3Daily_UVAerosolIndex	OMPS-NPP-TC_EDR_TO3_L3Daily_UVAerosolIndex-v1.0-2012m0705-2012m1211t1444…
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2012/07/05 00:00:00	TC_EDR_TO3_L3Daily	OMPS-NPP-TC_EDR_TO3_L3Daily-v1.0-2012m0705-2012m1211t144420.h5
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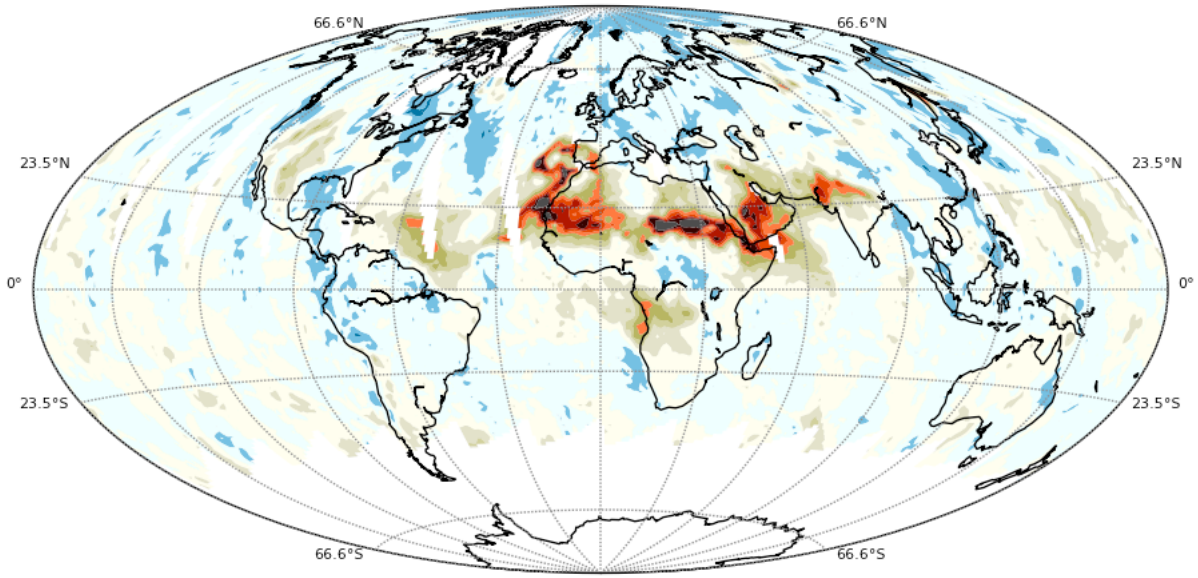
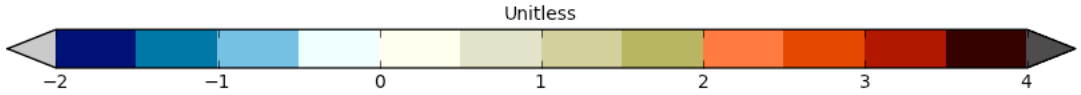
2012/07/05 00:00:00	TC_EDR_TO3_L3Daily_AerosolCloudKmz	OMPS-NPP-TC_EDR_TO3_L3Daily_AerosolCloudKmz-v1.0-2012m0705-2012m1211t15…
2012/07/05 00:00:00	LP_DAILYO3	OMPS-NPP-LP_DAILYO3-v1.0-2012m0705-2012m1026t052714.h5
2012/07/05 00:00:00	TC_EDR_TO3_L3Daily_OzoneAscii	OMPS-NPP-TC_EDR_TO3_L3Daily_OzoneAscii-v1.0-2012m0705-2012m1211t144420.txt
2012/07/05 00:00:00	NP_EDR_PV8_Daily	OMPS-NPP-NP_EDR_PV8_Daily-v1.0-2012m0705-2012m1211t144309.h5
2012/07/05 00:00:00	TC_EDR_TO3_L3Daily_UVAerosolIndexA…	OMPS-NPP-TC_EDR_TO3_L3Daily_UVAerosolIndexAscii-v1.0-2012m0705-2012m1211t…

Last Updated: May 9, 2013
NASA Official: Rich McPeters
Site Editor: Colin Seftor
Technical Contact: Adam Hollidge

UV Aerosol Index

2012-06-26 (day 178) Daily Gridded, Global Orbits = 03424 - 03449



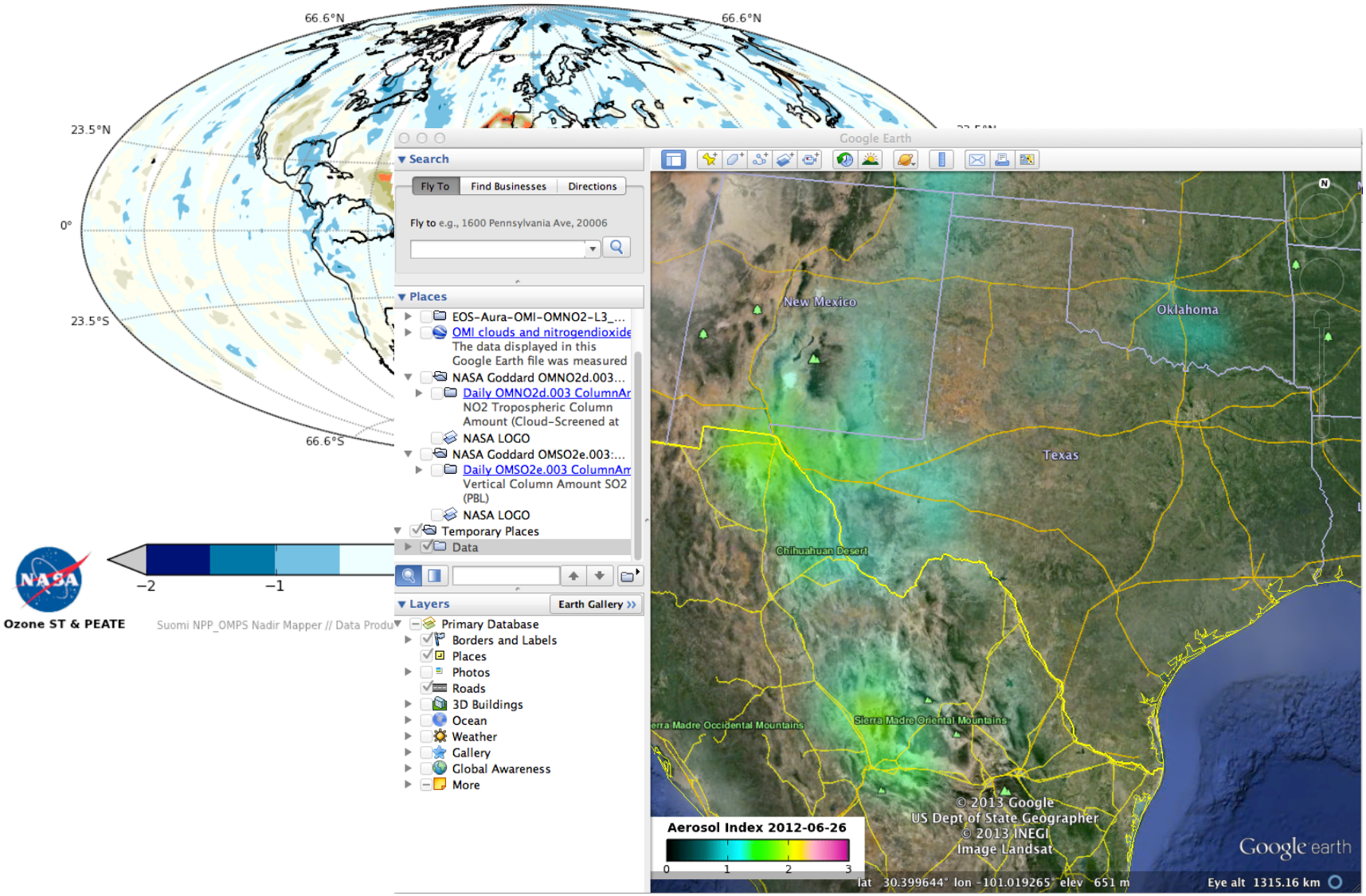


Ozone ST & PEATE

Suomi NPP_OMPS Nadir Mapper // Data Product = TC_EDR_TO3_L3Daily // PGE = TC_EDR_TO3_L3Daily-1.0.0 @ OZONE PEATE 2012-12-11 19:43Z

UV Aerosol Index

2012-06-26 (day 178) Daily Gridded, Global Orbits = 03424 - 03449



Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS)

Click image for alternate view

Status: Future, Pre-Formulation
Mission Category: Earth Systematic Missions, Decadal Survey, Tier 2

The Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS) mission will make global atmospheric column carbon dioxide (CO2) measurements without a seasonal, latitudinal, or diurnal bias. The mission will also measure also measure ambient air pressure and temperature. The measurements made by ASCENDS will allow the mission to: 1) quantify global spatial distributions of atmospheric CO2 on scales of weather models in the 2010-2020 era; 2) quantify the current global spatial distribution of terrestrial and oceanic sources and sinks of CO2 on 1 x 1 grids at weekly resolution; and 3) provide a scientific basis for future projections of CO2 sources and sinks through data-driven enhancements of Earth system process modeling.

Key Active Sensing of CO2 Emissions over Nights, Days, and Seasons Facts

Instruments: Multifrequency laser
Program Scientist(s): Ken Jucks

Related Applications:

- Carbon Management

Aerosol-Cloud-Ecosystems (ACE)

ACE

Click image for alternate view

Status: Future, Pre-Formulation
Mission Category: Earth Systematic Missions, Decadal Survey, Tier 2

The objectives of the Aerosol-Cloud Ecosystems (ACE) mission are to study aerosol and cloud types and properties and measure ocean productivity in the surface ocean layers. Data from ACE will improve climate models and air-quality forecasts and will be used in the prediction of climate change.

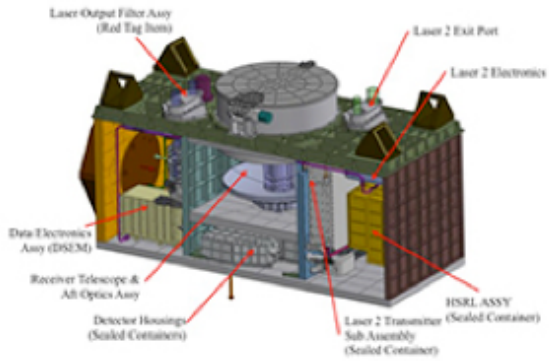
Key Aerosol-Cloud-Ecosystems Facts

Instruments:	Backscatter Lidar
	Doppler Radar
	Multi-angle Polarimeter
	Ocean Color Spectrometer
Program Scientist(s):	Hal Maring
	Paula Bontempi

Related Applications:

- Carbon Management
- Water Management

Cloud-Aerosol Transport System (CATS)



Status: Future
Mission Category: Other
Launch Date: September 2014

Science Goals:

- Provide near-real-time measurements of clouds and aerosols that can be assimilated into aerosol transport models
- Provide on-orbit tech demo for high rep-rate laser, photon-counting detection, and 355 nm laser operation in-space
- Provide risk reduction for future Earth Science missions
- Provide long-term (6 months to 3 years) operational science from ISS

Related Links:

- http://www.nasa.gov/mission_pages/station/research/experiments/1037.html

CATS is sponsored by NASA's Human Exploration and Operations Mission Directorate (HEOMD).

Key Cloud-Aerosol Transport System Facts

Mission/Portal Page:	http://cats.gsfc.nasa.gov
Launch Vehicle:	Japanese H-II Transfer Ve-hicle
Altitude:	350km
Inclination:	51.6°
Origination:	NASA
Principle Investigator(s):	Matthew J McGill, Goddard Space Flight Center, Greenbelt, MD, United States

Geostationary Coastal and Air Pollution Events (GEO-CAPE)

GEO-CAPE

Click image for alternate view

Status: Future, Pre-Formulation
Mission Category: Earth Systematic Missions, Decadal Survey, Tier 2

The objectives of the Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission are to 1) identify human versus natural sources of aerosols and ozone precursors; 2) study the dynamics of coastal ecosystems, river plumes, and tidal fronts; 3) observe air pollution transport in North, Central, and South America; 4) predict the tracks of oil spills, fires, and releases from natural disasters; 5) detect and track waterbourne hazardous materials; 6) measure coastal health; and 7) facilitate forecasts of air quality.

Key Geostationary Coastal and Air Pollution Events Facts

Instruments:	High-spatial-resolution hyperspectral spectrometer
	IR (Infrared) correlation radiometer
	Low-spatial-resolution imaging spectrometer
Program Scientist(s):	Ken Jucks
	Paula Bontempi

Related Applications:

- Carbon Management
- Coastal Management
- Public Health

Related Links:

- GEO-CAPE Homepage: http://geo-cape.larc.nasa.gov/

Global Atmosphere Composition Mission (GACM)

GACM

Click image for alternate view

Status: Future
Mission Category: Earth Systematic Missions, Decadal Survey, Tier 3

The objectives of the Global Atmosphere Composition Mission (GACM) mission are to measure ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction.

Key Global Atmosphere Composition Mission Facts

Instruments:	IR Spectrometer Microwave Limb Sounder UV Spectrometer
Program Scientist(s):	Ken Jucks

Related Applications:

- Air Quality

Joint Polar Satellite System (JPSS-1)

JPSS-1

Click image for alternate view

Status: Future
Mission Category: Inter-Agency Partnerships
Launch Date: 2017

Historical note: NPOESS 1330 LT orbit transferred to Joint Polar Satellite System (JPSS).

The Joint Polar Satellite System (JPSS) is the restructured civilian portion of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) that will make afternoon observations as it orbits Earth. The system includes the satellites and sensors supporting civil weather and climate measurements and a shared ground infrastructure with the Department of Defense weather satellite system.

NOAA is responsible for the JPSS program. NASA is the program's procurement agent, and the agency's Goddard Space Flight Center in Greenbelt, Md., is the lead for acquisition. Data and imagery obtained from JPSS will increase the timeliness, accuracy and cost-effectiveness of public warnings and forecasts of climate and weather events, reducing the potential loss of human life and property.

Polar-orbiting satellites observe Earth from space and collect and disseminate data on Earth's weather, atmosphere, oceans, land, and near-space environment and are able to monitor the entire planet and provide data for long-range weather and climate forecasts.

Key Joint Polar Satellite System Facts

Altitude:	833km
Inclination:	98.7°
Local Node:	1:30 p.m.
Instruments:	ATMS (Advanced Technology Microwave Sounder) CERES (Clouds and Earth’s Radiant Energy System) CrIS (Cross-Track Infrared Sounder) OMPS (Ozone Mapping and Profiler Suite) VIIRS (Visible/Infrared Imager/Radiometer Suite)

Joint Polar Satellite System (JPSS-1)

JPSS-1

Status: Future
Mission Category: Inter-Agency Partnerships
Launch Date: 2017

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here, oceans, land, and
climate forecasts.

Relevant Science Focus Areas:

- Weather

Relevant Science Questions:

- How is the global Earth system changing?
- What are the primary forcings of the Earth system?

Related Applications:

- Weather Prediction

Related Links:

- JPSS Homepage: http://www.nesdis.noaa.gov/jpss/
- Suomi NPP Homepage: http://jointmission.gsfc.nasa.gov/

Key Joi

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Instruments:

ATMS (Advanced Technology Microwave Sounder)
CERES (Clouds and Earth’s Radiant Energy System)
CrIS (Cross-Track Infrared Sounder)
OMPS (Ozone Mapping and Profiler Suite)
VIIRS (Visible/Infrared Imager/Radiometer Suite)

Orbiting Carbon Observatory 2 (OCO-2)

OCO-2

Click image for alternate view

Status: Future, Implementation
Mission Category: ESSP, A-Train
Launch Date: July 2014
Launch Location: Vandenberg Air Force Base, CA

The second Orbiting Carbon Observatory (OCO-2) mission is designed to provide space-based global measurements of atmospheric carbon dioxide (CO2) with the precision and resolution needed to identify and characterize the processes that regulate this important greenhouse gas. With its three high-resolution grating spectrometers, data collected by OCO-2 could be combined with meteorological observations and ground-based CO2 measurement to help characterize CO2 sources and sinks on regional scales at monthly intervals for 2 years.

Key Orbiting Carbon Observatory 2 Facts

Mission/Portal Page:	http://science.nasa.gov/missions/oco-2/
Launch Vehicle:	Delta-2
Altitude:	705km
Inclination:	98.2°
Local Node:	1:15 p.m.
Instruments:	Three high-resolution grating spectrometers
Project Scientist(s):	Mike Gunson
Deputy Project Scientist(s):	Annmarie Eldering

Orbiting Carbon Observatory 2 (OCO-2)

Related Publications:

- Orbiting Carbon Observatory (OCO) (Mission Brochures - 7.73 MB)

Relevant Science Focus Areas:

- Carbon Cycle, Ecosystems, and Biogeochemistry
- Earth Surface and Interior

Relevant Science Questions:

- How does the Earth system respond to natural and human-induced changes?
- How is the global Earth system changing?
- How will the Earth system change in the future?

or 2

Science Goals:

- Improve our understanding of the geographic distribution of CO2 sources and sinks (surface fluxes) and the processes controlling their variability on seasonal time scales.
- Validate a passive spectroscopic measurement approach and analysis concept that is well suited for future systematic CO2 monitoring missions.

Related Applications:

- Air Quality
- Carbon Management
- Public Health

Related Links:

- OCO-2 Homepage: http://oco.jpl.nasa.gov/mission/

Satellite Homepages

- Aura Homepage: http://aura.gsfc.nasa.gov/
- Aura Validation Data Center (AVDC): http://avdc.gsfc.nasa.gov/
- AIRS Homepage: http://airs.jpl.nasa.gov/
- MOPITT Homepage: http://www.acd.ucar.edu/mopitt/

The Goddard Earth Sciences Data and Information Services Center (GES-DISC) – Search tool for all NASA satellite and other platform data, i.e. ground based, campaign, model, etc.

- **http://disc.sci.gsfc.nasa.gov**
  - Reverb global search tool: http://reverb.echo.nasa.gov
  - Mirador Search/Get date: http://mirador.gsfc.nasa.gov
  - GIOVANNI: http://disc.sci.gsfc.nasa.gov/giovanni
  - Near-Real Time Data: http://disc.sci.gsfc.nasa.gov/nrt/

Remote Sensing Capabilities - Current Missions

Sensor	Launch Date	Design Length	Resolution	End Date/Problems
Terra - MODIS	1999	5 Years	10/3/(1) KM	2015 -2016
Terra – MISR	1999	5 Years	17.6 KM	2015 -2016
Aqua - MODIS	2001	5 Years	10/3/(1) KM	2018
Aura – OMI	2004	6 Years	13 x 27 KM	Loss of data
Parasol - POLDER	2004	2 Years	18 KM	Out of A-Train
Calipso - CALIOP	2006	3 Years	5 Km x .2 KM	
NPP - VIIRS	2011	5 Years	6 KM	
NPP - OMPS	2011	5 Years	6 KM	
TES				
MOPITT				
Geostationary				
MSG - SEVIRI	2005		10 KM	
GOES - GASP	2006	5 Years	4 KM/30 Min	

Remote Sensing of Aerosol Capabilities - Upcoming Missions

Sensor	Launch Date	Measurements	Notes
EarthCARE	2015	Aerosols/Clouds	LIDAR Narrow swath
OCO-2	2014	CO2/Aerosols	7 KM Resolution/7 Yr.
TROPOMI	2014	Aerosols/Gases	Few bands
Sentinel-3	2014 - 2020	Aerosols	Improve A-Train Capabilities
CATS	2014	Aerosols/Clouds	NRT measurements for assimilation into models
Geostationary			
GOES-R	2015	Aerosols	North America
TEMPO	2018-2019	Aerosol & Trace Gases	Cluster
Sentinel-4	2019	Aerosol & Trace Gases	Cluster
MP-GEOSat	2018	Aerosol & Trace Gases	Cluster
GEO-CAPE	2020	Aerosols	North America

Models – Future Prospects

Models

Increased computing power

Increased understanding of processes

Increasing availability of satellite data

The Future of Remote Sensing and Air Quality Applications

Current Status Ground Sensors and in-Situ Data

1. A major source of data for priority pollutants Ozone and PM
2. Provide Validation of Satellite Measurements
3. Provide Necessary Information for Satellite Retrievals
4. Data can improve process models.
5. Networks can be used for statistical modeling

Ground Instruments

The Weakest Link

2400 out of 3100 counties in the US (31% of total population) have no PM monitoring in the county.

Most of the ~1,200 monitors operate every 3 or 6 days.